PHENIX Status & Plans

- New Results and Accomplishments
- PHENIX Operations
  Efficiency & Increased luminosity
- Future Physics
  Compelling physics questions
  Upgrades
  Exploiting VTX for new physics

Barbara Jacak

for the PHENIX Collaboration

slides can be found at:

http://www.phenix.bnl.gov/WWW/publish/jacak/sp/presentations/DOErev_jul09/

PHENIX

PHENIX Detector

Central Arm Tracking
- Drift Chamber
- Pad Chambers
- Time Expansion Chamb.

Muon Arm Tracking
- Muon Tracker

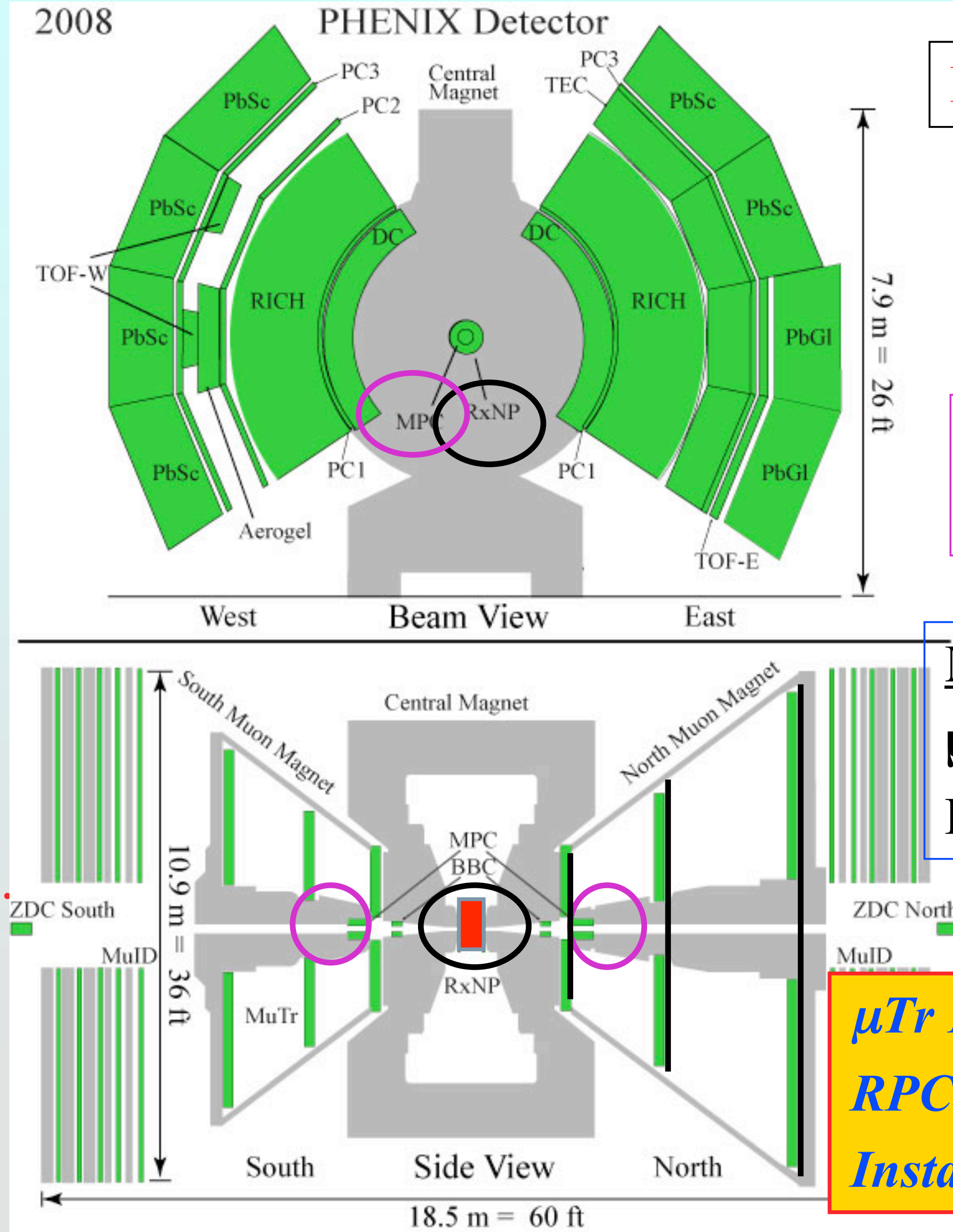
Calorimetry
- PbGl
- PbSc
- MPC

Particle Id
- Muon Identifier
- RICH, HBD
- TOF E & W
- Aerogel
- TEC

Global Detectors
- BBC
- ZDC/SMD Local Polarim.
- Forward Hadron Calo.
- RXNP

DAQ and Trigger System

Online Calib. & Production



Hadron Blind

Muon Piston Calorimeters

Muon Trigger:
μTr FEE North
RPC prototype

μTr FEE South
RPC-3 North
Install for Run-10

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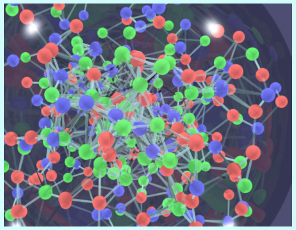
PHENIX Approach



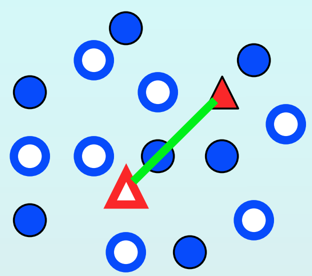
- **Key physics goals**
  - **Establish nature of RHIC's new state of matter**
    - **T, η/s, energy transport, color screening**
  - **Spin of the proton via**
    - **hadrons, direct photon, J/ψ, correlations**
  - **Gluon distribution in cold nuclear matter**
- **PHENIX philosophy**
  - **Rare process sensitivity → hadrons, leptons, photons**
  - **High rate capability + selective triggers**
  - **Precision measurement in multiple channels**
    - ***high p_T hadrons, multi-particle correlations, jets***
    - ***direct γ, γ + jet, virtual γ production***
    - ***light & heavy vector mesons, open heavy flavor***
- ***Keep up with data analysis while: taking data, constructing upgrades, writing high impact papers***

Recent Physics Results

NB: these are NEW channels!

Color screening?

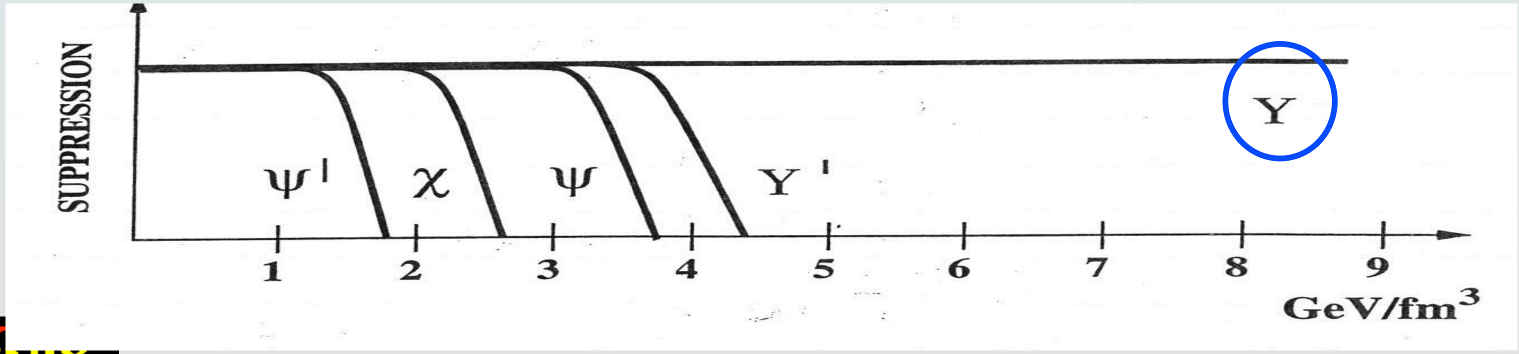
J/ψ (bound c and $\bar{c}$ quarks) suppression!



Test color screening length (λ_D) :

do bound c + $\bar{c}$, b+$\bar{b}$ survive the medium?

does QGP screening kill the bigger ones?



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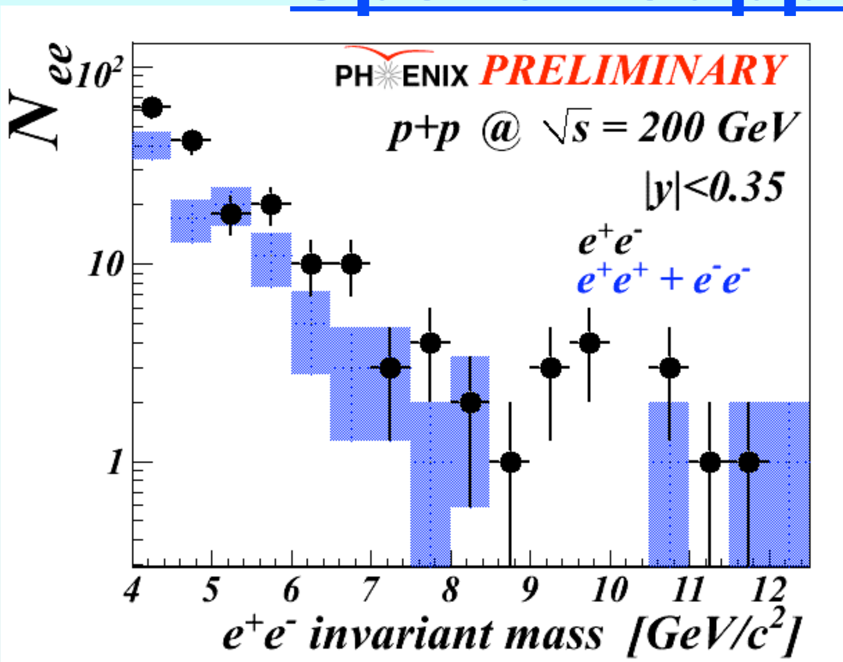
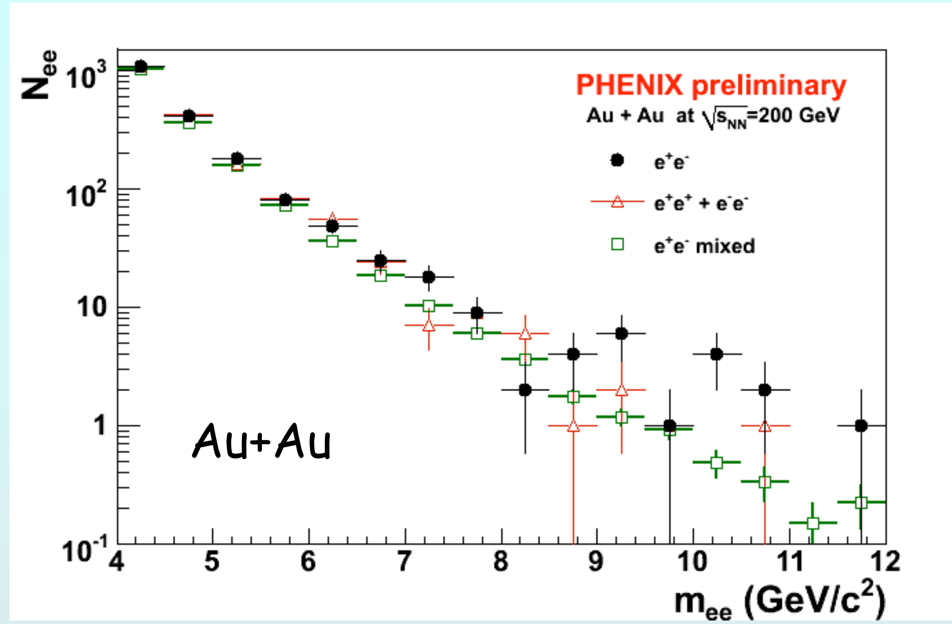
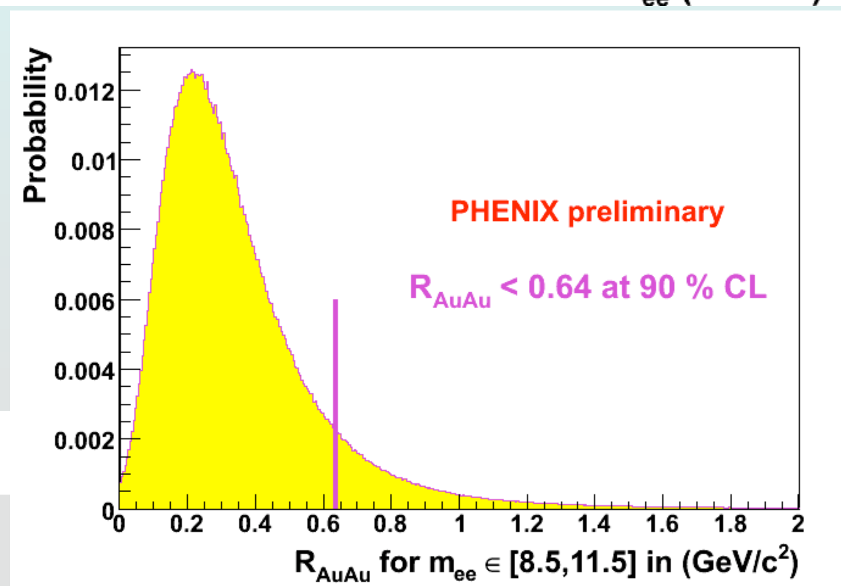
Upsilon suppressed in Au+Au!





	p+p	Au+Au
N[8.5,11.5]	10.5(+3.7/-3.6)	11.7(+4.7/-4.6)
$N_{J/\Psi}$	2653 ±70±345	4166 ±442(+187/-304)
$R_{AA}(J/\Psi)$	---	0.425 ±0.025±0.072

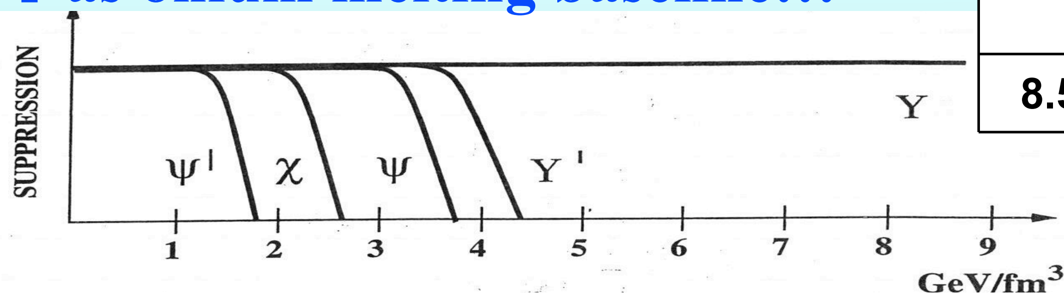


R_{AA} [8.5,11.5] < 0.64 at 90% C.L.

Should ϒ's be suppressed?

	$R_{AuAu}(y=0)$
J/Ψ	0.425 ± 0.025 ± 0.072
8.5<M<11.5 GeV	< 0.64 at 90% C.L.

ϒ as onium melting baseline…



- σ_{abs} of ϒ ~1/2 of J/Ψ: E772 (*PRL 64, 2479 (19*
  - nuclear matter absorption → R
- Lattice QCD: in Au+A
- **absorpt**

need … **naïve speculation!**

  - … 07314

ALSO:

- ϒ in a… gion
- CDF: 5… from χ_b (p_T>8 GeV/c) & ~25%? at our p_T
  - *PRL… (2000) 2094*

Need more data in both Au+Au and p+p
also d+Au to control cold nuclear matter effects
Muon arms with FVTX will contribute tremendously
Enhanced central arm acceptance with VTX!

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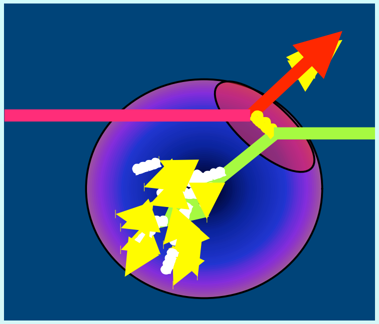
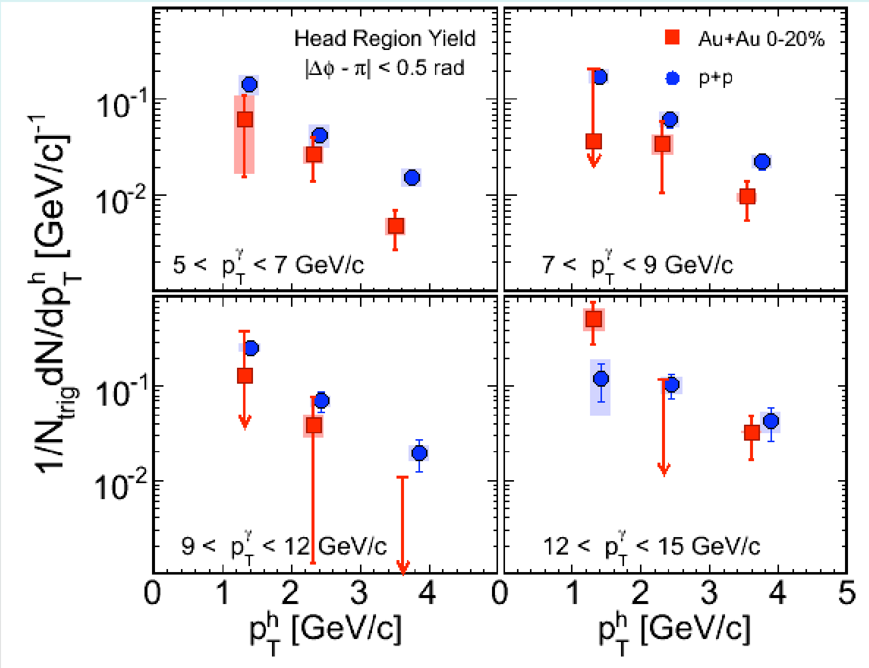
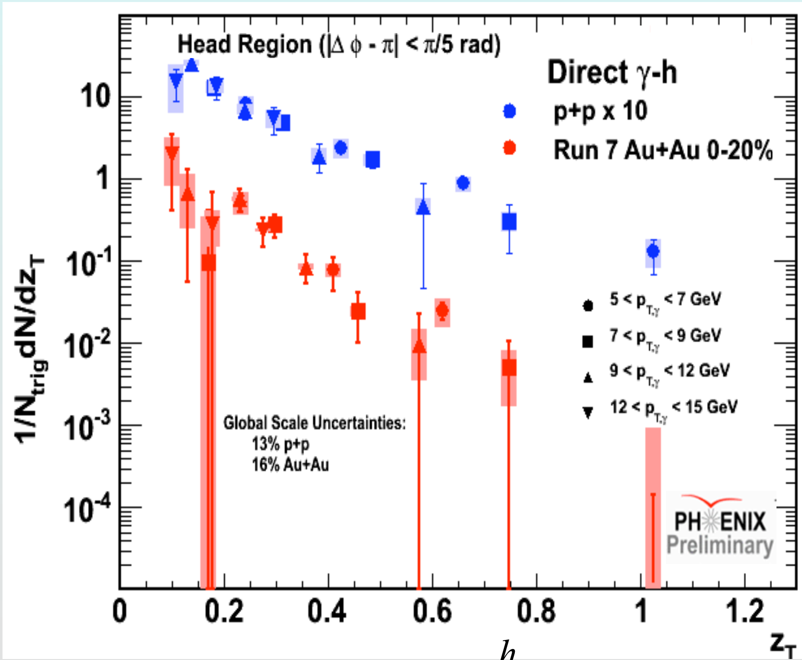
γ-jet → medium modified jet fragmentation



- ***Golden* channel**
  γ tags jet energy → quantify medium impact
- Unfold direct γ correlations: inclusive - decay
- Map away side hadron distribution → jet fragmentation function

arXiv:0903.3399





γ_{direct}-h

$$z_T = \frac{p_T^h}{p_T^{trig}}$$

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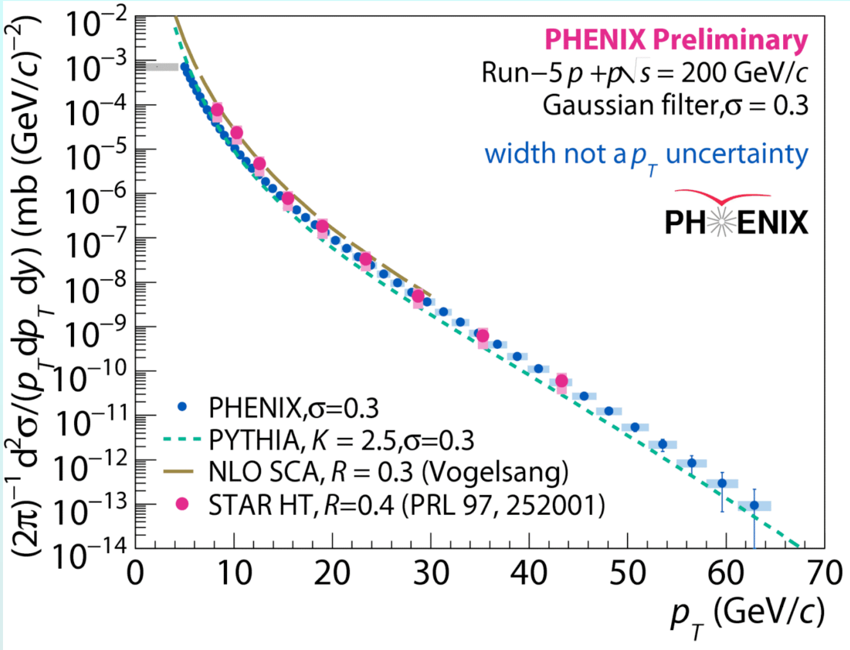
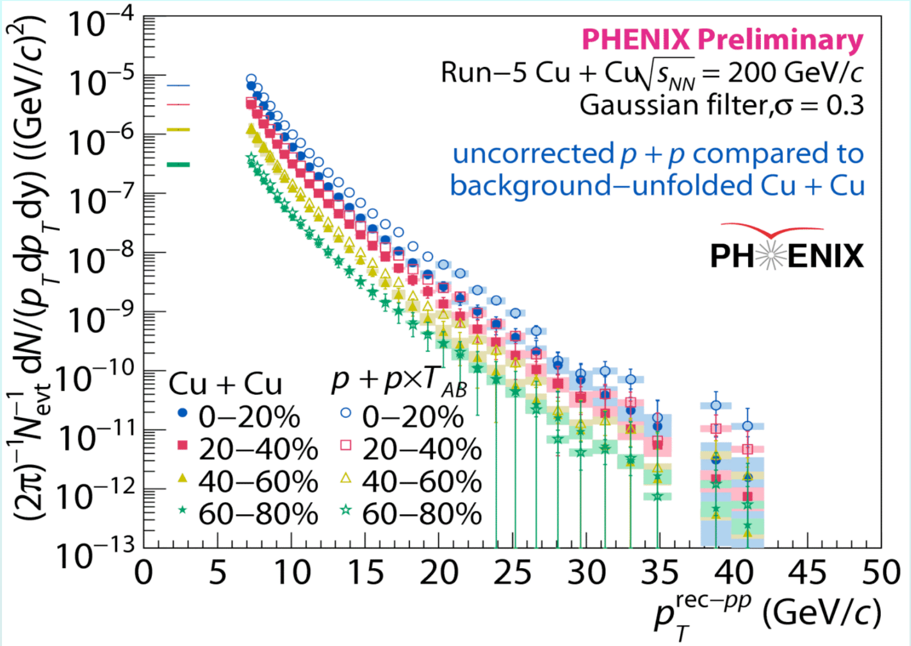
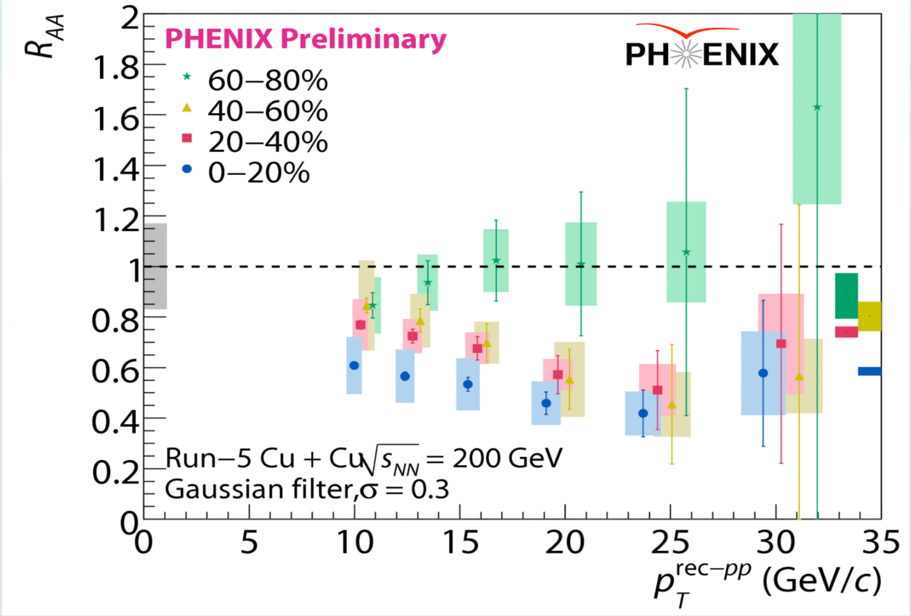
Full jet reconstruction in PHENIX







first ΔG publication from Run-6

PRL **103,** 012003 (2009) PHYSICAL REVIEW LETTERS week ending 3 JULY 2009

Gluon-Spin Contribution to the Proton Spin from the Double-Helicity Asymmetry in Inclusive π^0 Production in Polarized $p + p$ Collisions at $\sqrt{s} = 200$ GeV

A. Adare,[12] S. Afanasiev,[26] C. Aidala,[37] N. N. Ajitanand,[54] Y. Akiba,[48,49] H. Al-Bataineh,[43] J. Alexander,[54] K. Aoki,[31,48]

PRL **103,** 012003 (2009) PHYSICAL REVIEW LETTERS week ending 3 JULY 2009

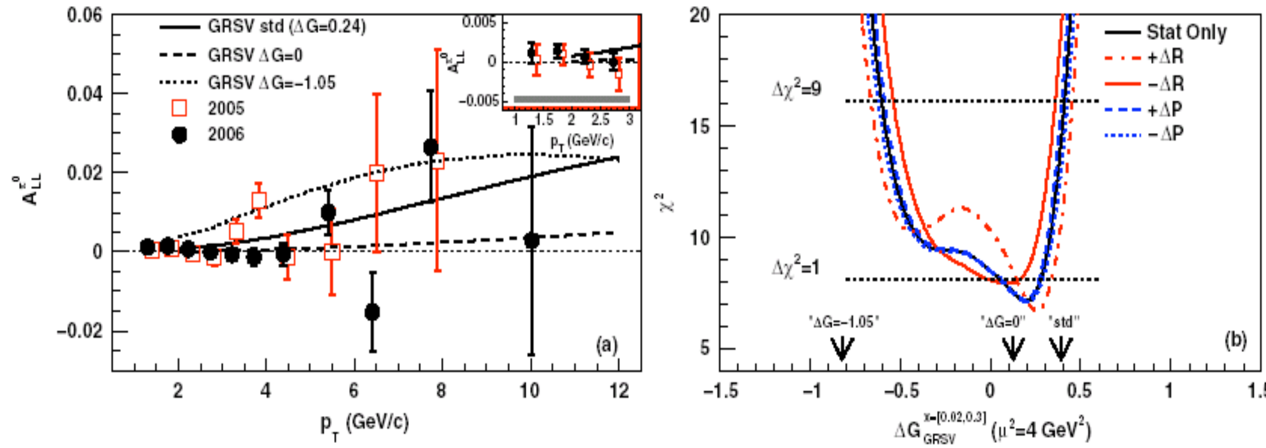


FIG. 2 (color online). (a) Asymmetry in π^0 production as a function of p_T. The error bars are statistical uncertainties. An 8.3% scale uncertainty due to the uncertainty in beam polarization is not shown. The p_T independent uncertainty of 7×10^{-4} due to relative luminosity is shown only in the inset as a shaded bar. For comparison, we also show our 2005 result. NLO pQCD expectations based on several inputs for ΔG in the GRSV parametrization are plotted. (b) The χ^2 profile as a function of $\Delta G_{\mathrm{GRSV}}^{[0.02,0.3]}$ using the combined 2005 and 2006 data considering only statistical uncertainty, or also varying by $\pm 1\sigma$ the two primary experimental systematic uncertainties, from beam polarizations ($\pm\Delta P$) and relative luminosity ($\pm\Delta R$).

Almost the same day Run 9 ended, Run 6 π^0 A_{LL} was published in *PRL*

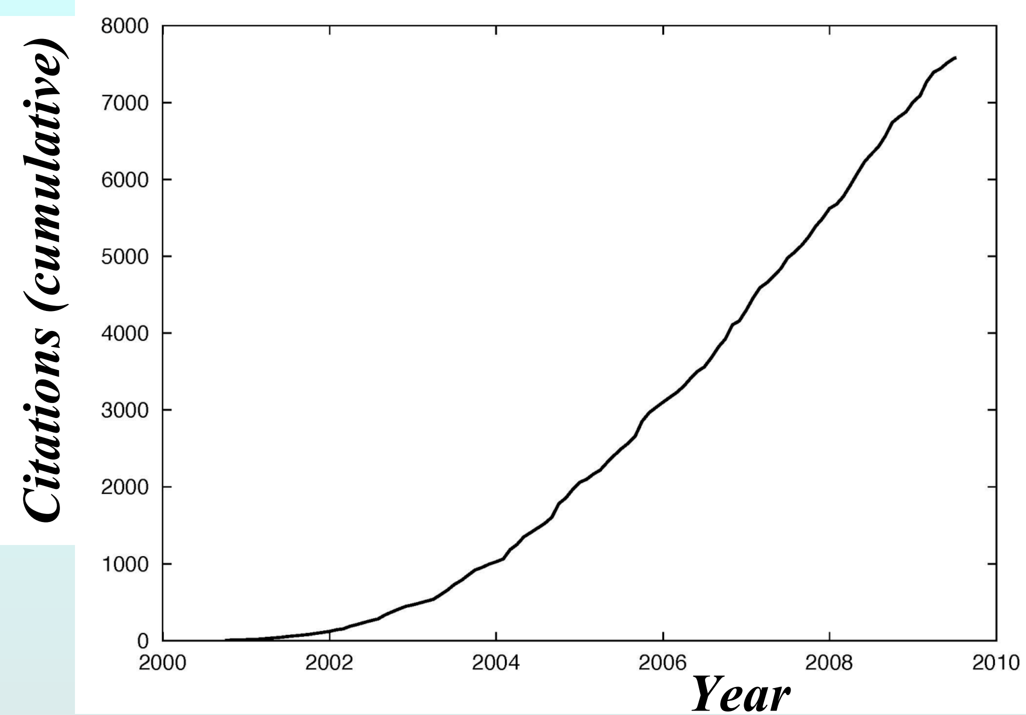
Recent papers

- **First direct photon-jet correlations at RHIC** *0903.3399*
- **Reaction plane dependence of high p_T π^0 suppression** *0903.4886*
- **c/b separation in p+p collisions: e-h/e^+e^-** *0903.4851, PLB670,313 ('09)*
- **π^0 σ and A_{LL} in 62.4 GeV polarized p+p** *PRD79,012003(2009)*
- **Double helicity asymmetry of π^0 in 200 GeV p+p** *PRL103, 012003 (2009)*
- **T_{init} from thermal photon emission** *0804.4168*
- **First measurement of J/ψ photoproduction at RHIC** *0903.2041*
- **Charged kaon HBT** *0903.4863*

+ additional papers on correlations and fluctuations in the bulk medium in Au+Au, as well as systematic studies of elliptic flow measured several different ways

Scientific impact - high & still growing!

- **Since 2001:**
  78 publications (47 PRL)
- **> 7580 citations**
- **Renowned papers!**
  White paper -
  725 citations
  Jet quenching discovery
  513 citations



+ 4 other physics papers with > 250 citations
+ 18 more papers with ≥ 100 citations
+ 27 additional 50+ Topcite papers

Dihadron correlations: PRC78, 014901, 2008 (primary author J.Jia)
Most cited Nuclear Experiment paper of 2008, 2nd of all Nuclear
#73 most cited of ALL 2008 papers! (SPIRES)

RHIC has broad intellectual impact!

RHIC Scientists Serve Up "Perfect" Liquid

New state of matter more remarkable than predicted -- raisi
questions

Monday, April 18, 2005

ScienceNews
MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

http://www.sciencenews.org/view/generic/id/45408

Home News News item

GRAPHENE GAINS NEARLY PERFECT LIQUID STATUS

Scientists have found the electrons in a layer of carbon atoms can become a strongly interacting swirling soup

By Rachel Ehrenberg

Web edition : Wednesday, July 8th, 2009

7) **Viscosity in strongly interacting quantum field theories from black hole physics.**
P. Kovtun, D.T. Son, A.O. Starinets (Washington U., Seattle) . INT-PUB-04-09, UW-PT-04-04, Mar 2004. 8pp.
An Essay submitted to 2004 Gravity Research Foundation competition.
Published in **Phys.Rev.Lett.94:111601,2005**.
e-Print: **hep-th/0405231**

TOPCITE = 250+
References | LaTeX(US) | LaTeX(EU) | Harvmac | BibTeX | Keywords | Cited 495 times
Abstract and Postscript and PDF from arXiv.org (mirrors: au br cn de es fr il in it jp

hold true — the amount of time it takes to find your keys,
s on how late you are. Similarly, the rate that electrons
erial is closely linked to its temperature. But graphene —
t's only one atom thick — doesn't conform to such rules.
ture range, graphene's electrons should become a
wirling soup, scientists report online July 6 in *Physical*

that graphene's electrons are behaving like a nearly
y turbulent with extremely low viscosity. Such properties
approaches the "quantum critical point," a phase transition that breaks the rules of ordinary physics. While a block of ice melts into water only within a narrow temperature range, the transition to a perfect liquid is believed to happen at a wide range of temperatures above this quantum critical point.

To understand the dynamics of graphene's interacting electrons, Markus Müller of the Abdus Salam International Center for Theoretical Physics in Trieste, Italy, and colleagues used quantum kinetic theory to calculate the ratio of graphene's viscosity to its entropy — a measure of gloopyness to disorder in the system. Graphene's ratio comes close to the theoretical lower bound that physicists have calculated for that ratio, and close to the low ratio observed in quark-gluon plasma, the superhot state of matter that existed just after the Big Bang. Instead of behaving like a gas, the quark-gluon plasma behaved more like a soup with extremely low viscosity, physicists learned in experiments at the Relativistic Heavy Ion Collider at Brookhaven National Laboratory on Long Island.

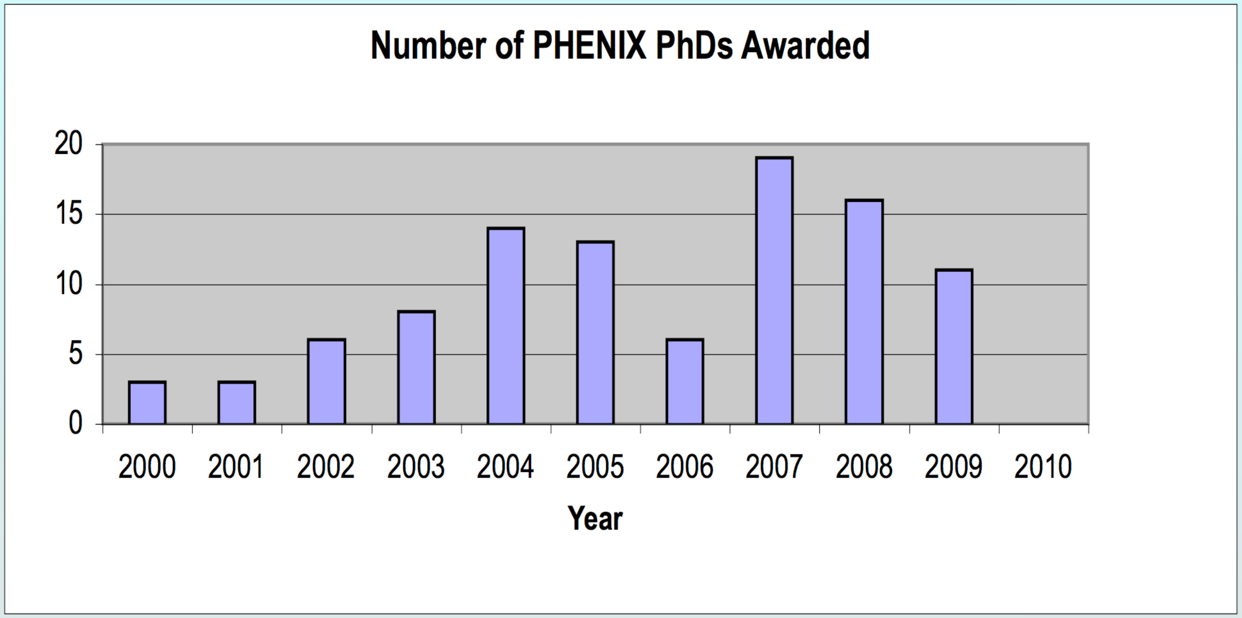
J Low Temp Phys (2008) 150: 567–576
DOI 10.1007/s10909-007-9589-1

Is a Gas of Strongly Interacting Atomic Fermions a Nearly Perfect Fluid?

A. Turlapov · J. Kinast · B. Clancy · Le Luo ·
J. Joseph · J.E. Thomas

PHENIX attracts many talented young people

89 Ph.D. degrees earned on PHENIX

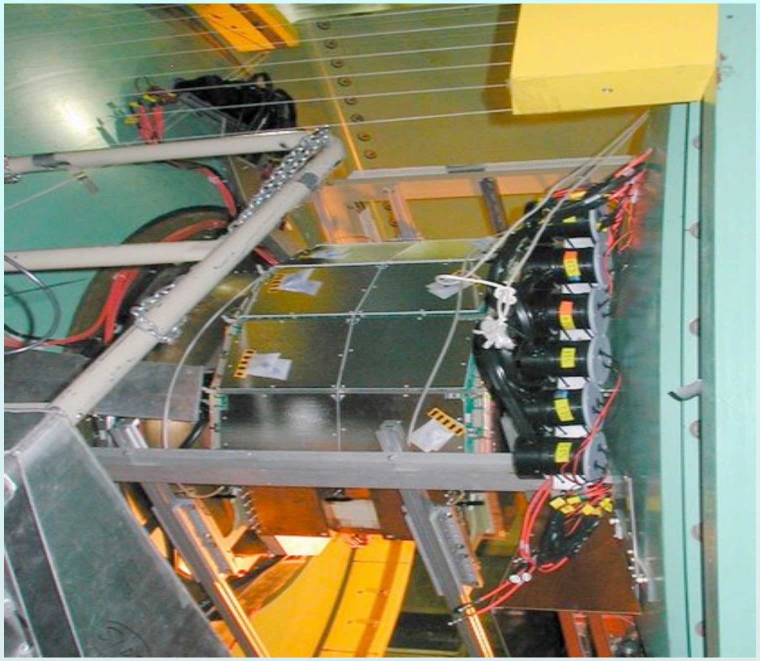


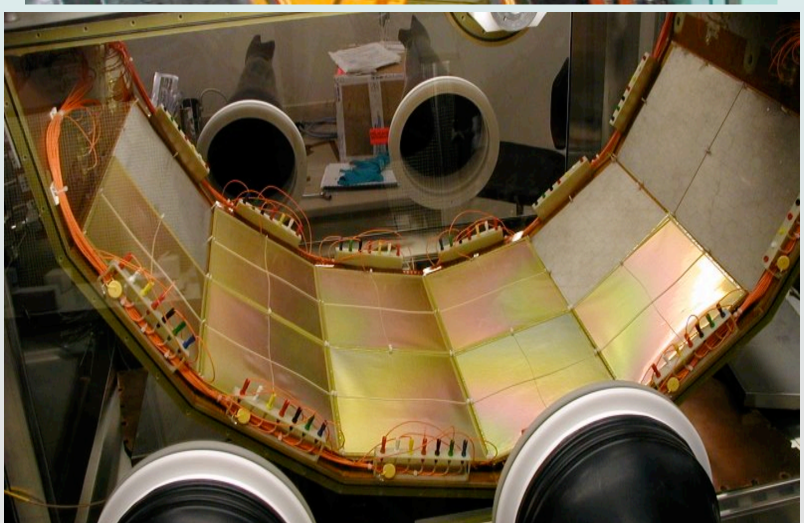
15 Masters/Diploma theses

+ 79 Ph.D. students working

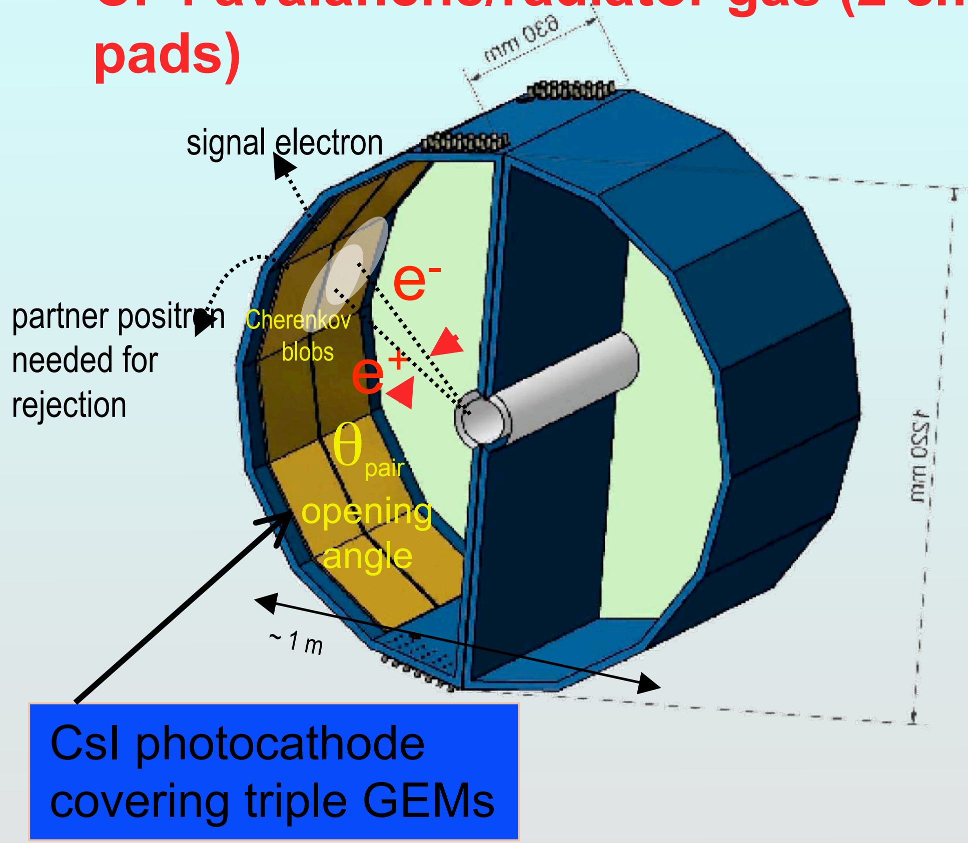
In the just completed Run-9

(Re-built) Hadron Blind Detector - HBD



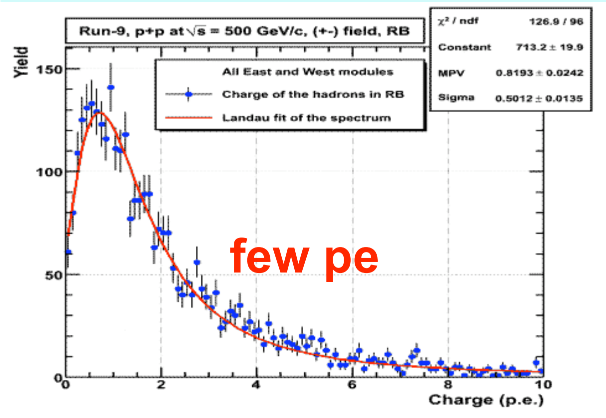


Windowless Cerenkov detector with CF4 avalanche/radiator gas (2 cm pads)



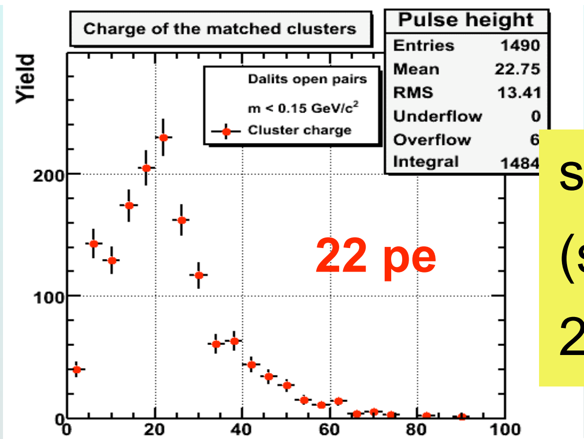
Removes Dalitz & conversion pairs (small opening angle)

HBD Works! (very well)

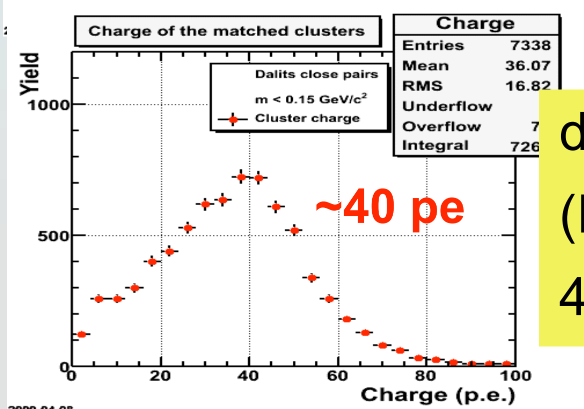


hadron blind!

- Rebuilt for Run-9
- Available for use in Runs 9, 10
- Will be replaced by VTX after Run-10



signal (separated electrons): 22 photo-electrons



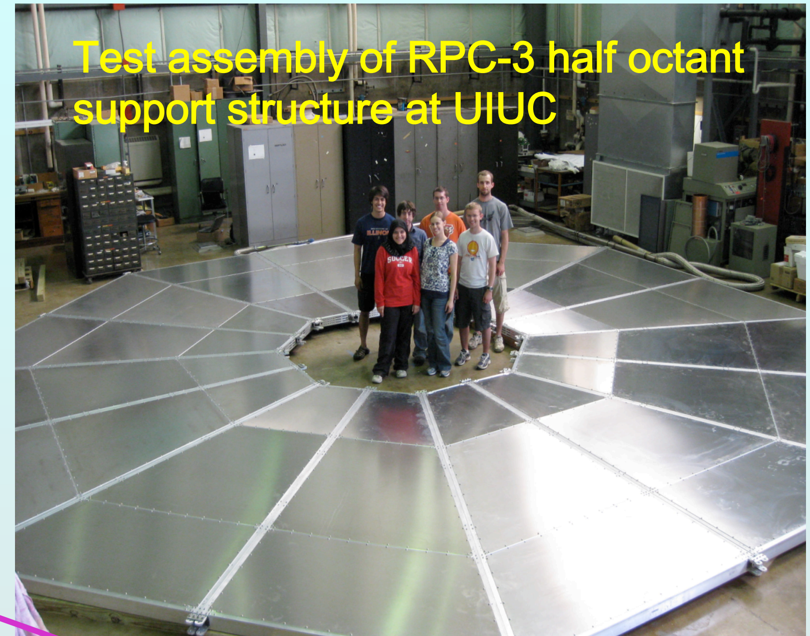
double e background (Dalitz, conversion): 40 photo-electrons

Clear separation of signal and background

Suppression of background pairs increases effective statistics by factor 8-16

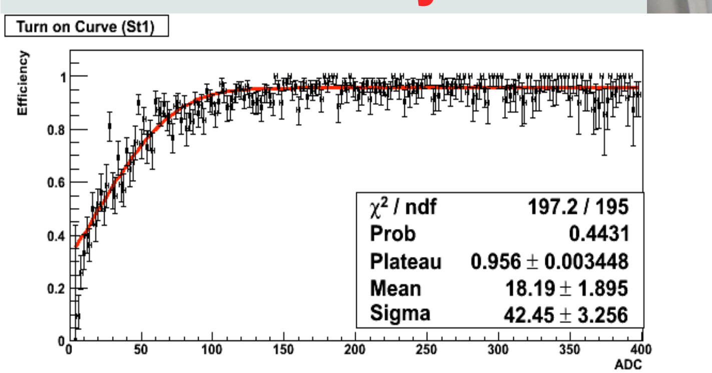
MuTrig Status: ready for Physics in Run-11

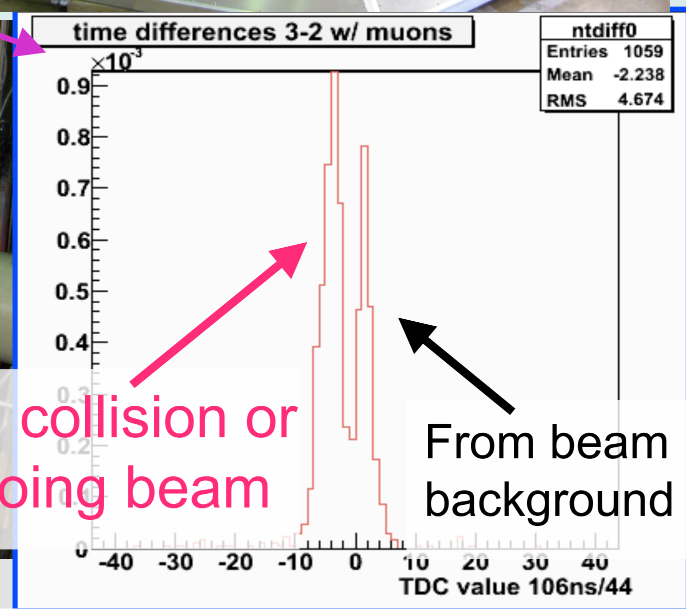
- Engineering run for sectors in 2 RPC planes on south arm
- Timing info helped understand background in first 500 GeV run



MuTr.N operational in Run-9

Good efficiency!



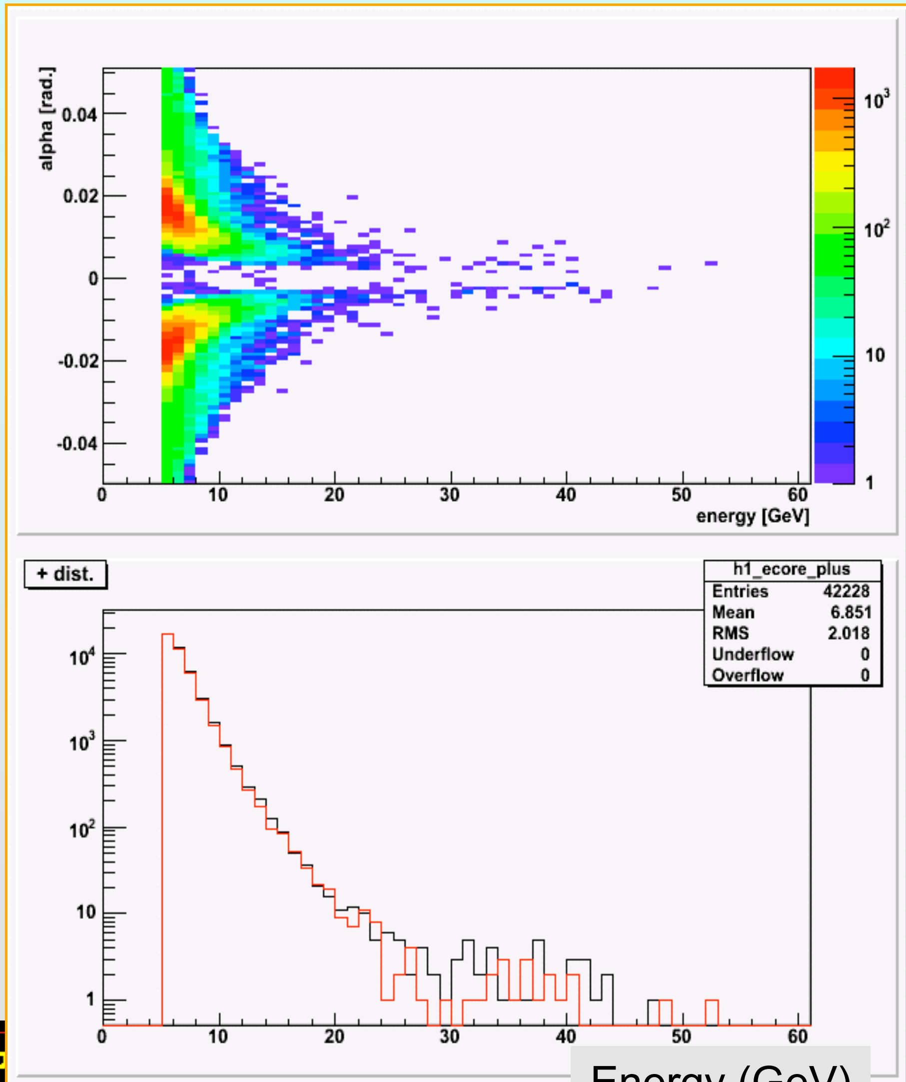


From collision or out going beam

From beam background

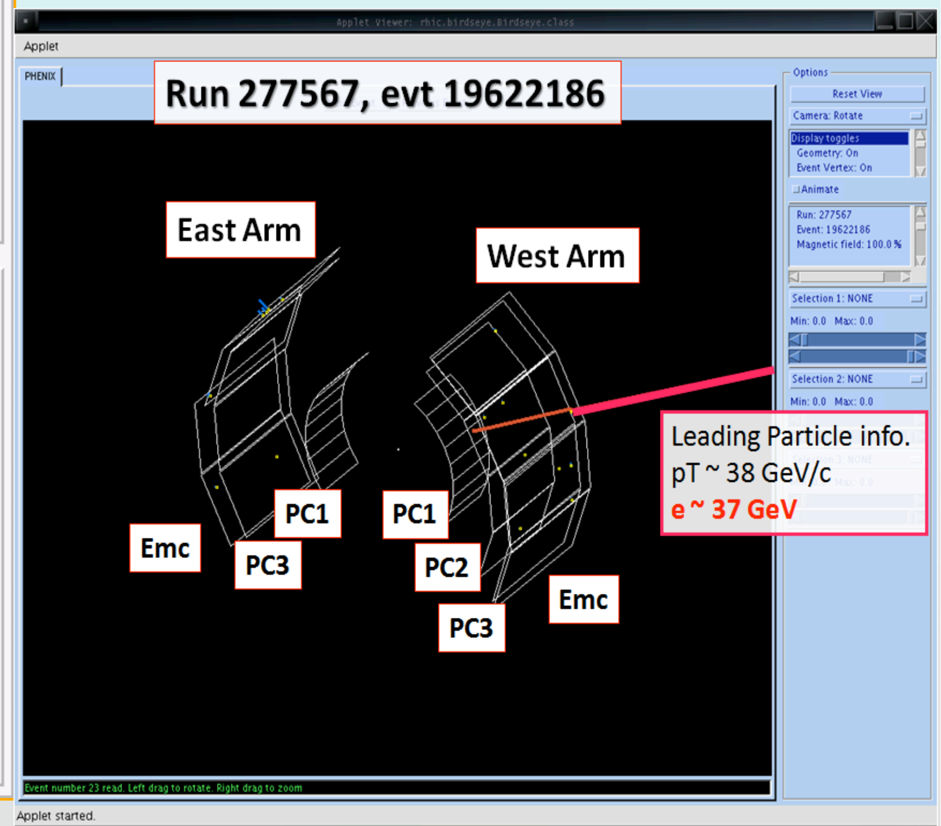
RUN-9 500 GeV: First Look at W

Goal: sea quark polarization from W-boson asymmetry



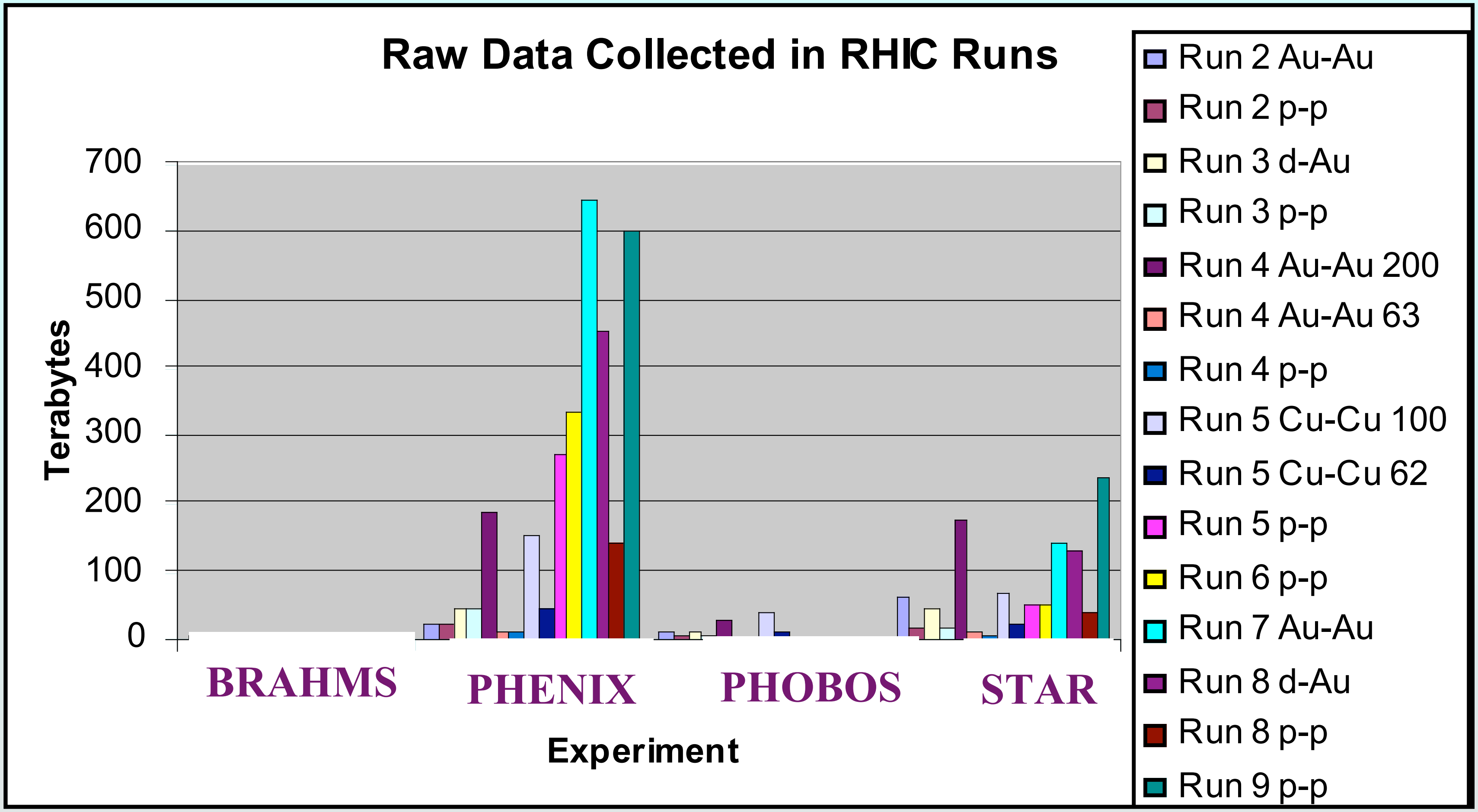
Fast track analysis by W task force

A Typical W-like event
Single electron from W decay



Operations

PHENIX data > 0.5 PB per year

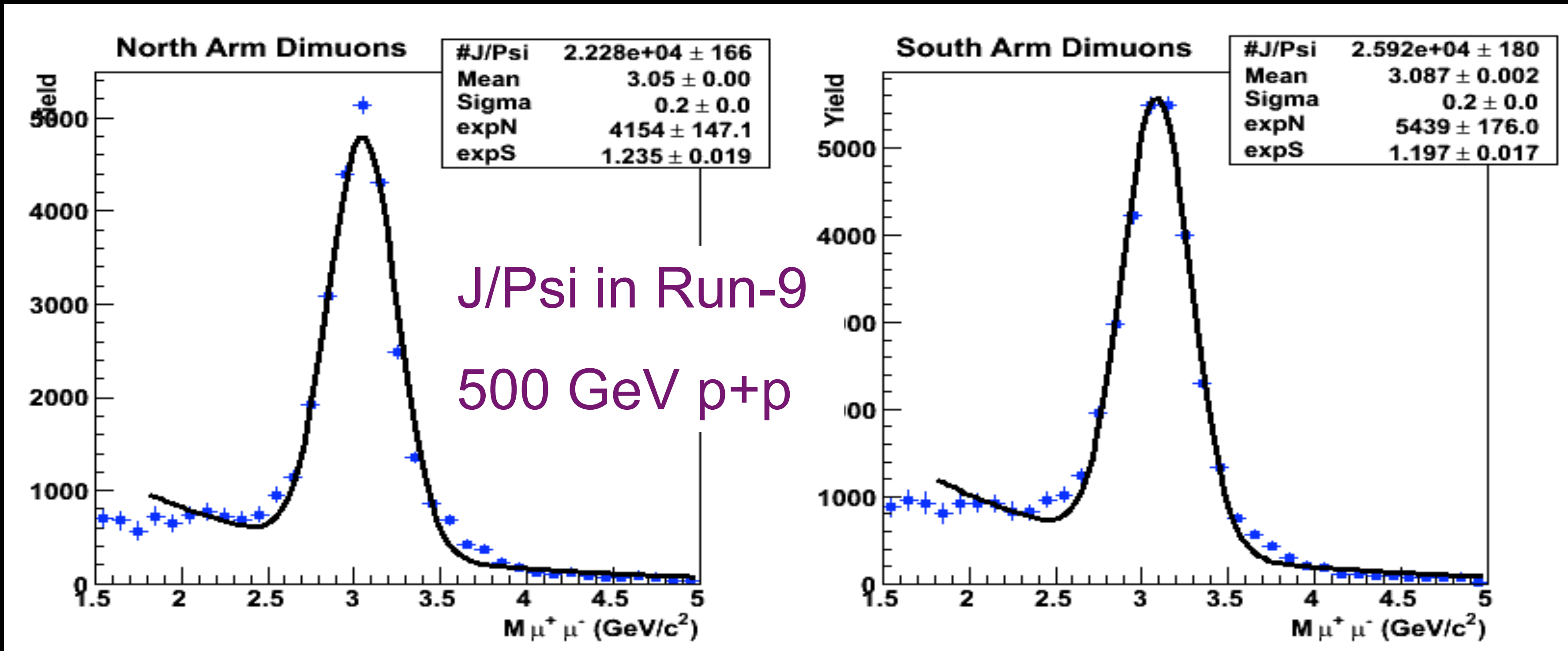


- **Production teams drawn from collaboration**

Run-7: Carla Vale, Run-8: Alex Linden-Levy,

Run-9: Jeff Mitchell

online calibration & reconstruction!

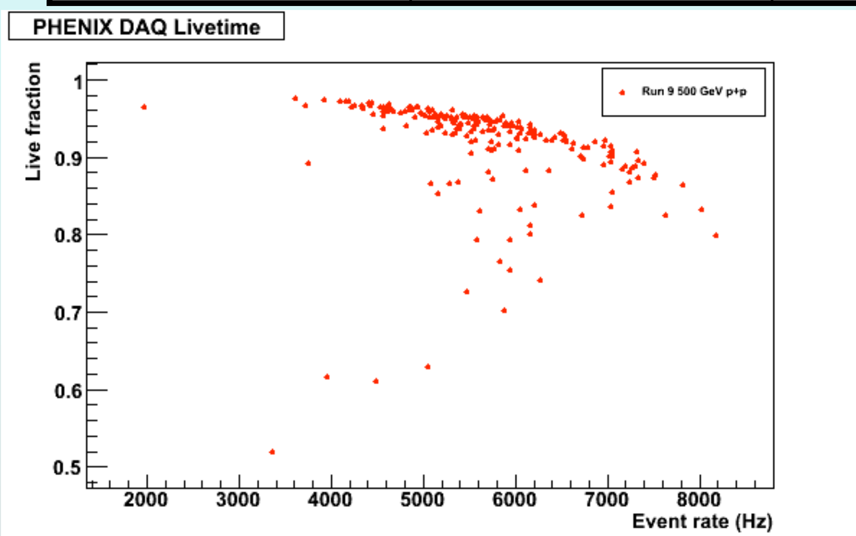


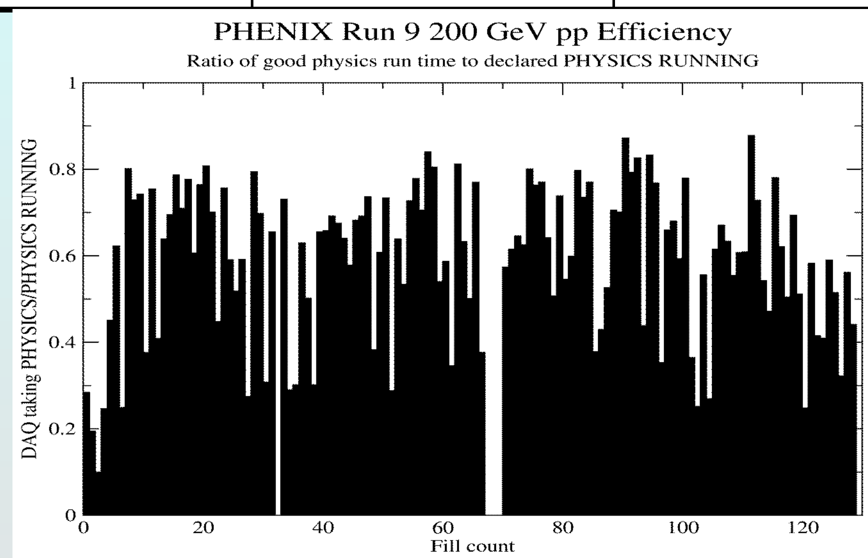
- Reconstruction for Run-8 is complete in Japan, RCF, PHENIX Counting House
- Reconstruction of 500 GeV p+p in progress
- Run-9 production will complete before Run-10 begins.
- PHENIX data production keeping pace with data taking!

PHENIX DAQ efficiency

"Livetime": fraction of delivered luminosity *within ± 30 cm* sampled by the PHENIX Level-1 triggers. Vertex cut = 56% (>Run-8 due to bunch shape)

Year	2007	2007 (last 2 wks)	2008	2009
Species	Au+Au	Au+Au	d+Au, p+p	p+p
Livetime	82%	90%	89%	~89%





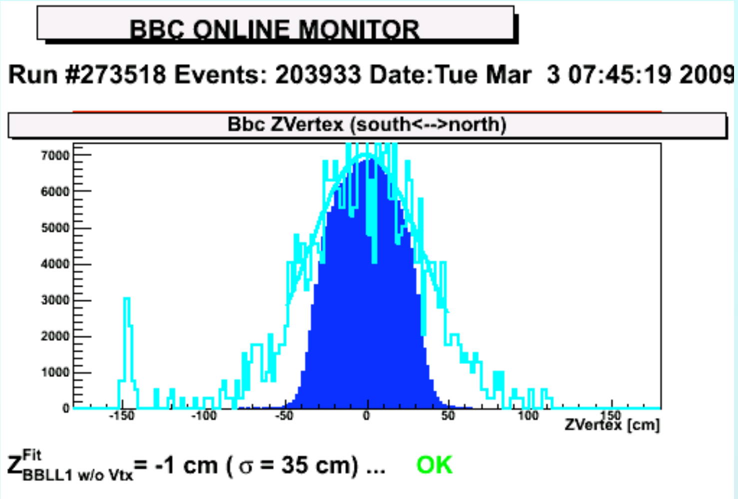
Livetime similar -> DAQ improvements but events larger (HBD, MuTrig)

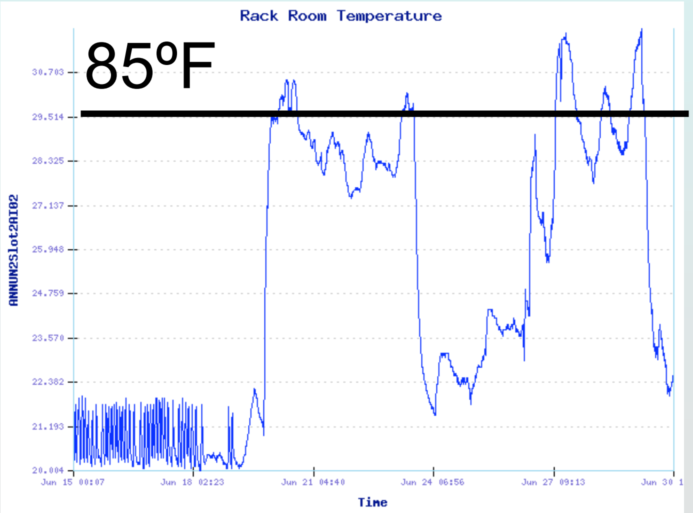
DAQ uptime = ~60% (vs. ~75% Run-8) counting all DAQ operation

took more calibrations for systematics

Total ~ 33% - similar to last year

The issues





1) The vertex distribution σ = 35 cm

need it narrowed (56 MHz RF?)

but VTX detector is ± 10 cm

2) Must ramp HV once store is stable

HV control software modification

maybe a modest gain

Longer stores → fewer end effects

3) Need to keep DAQ *running*

Improve basic infrastructure (cooling)

PHENIX

Utilizing increased luminosity

- **Now:**

  DAQ 5kHz bandwidth

  7kHz p+p ~90% live

  Before Run-7:

  record *every* Au+Au minbias event

  In Run-7: 80% of 7 kHz

  In p+p, Lvl1 triggers reduce 200-400 kHz rate to ~6kHz of useful events

  →PHENIX effectively samples full luminosity for all rare channels

- **Future:**
  - 7MHz p+p@500GeV
  - 2MHz p+p@200GeV
  - 40kHz Au+Au

  Event size *1.7 with Si detectors

- **Previous trigger strategy insufficient**

PHENIX

DAQ/Trigger 2010 Upgrade Plan

Replace	EMCAL FEE trigger match/rejection ($e^{\pm}$)	Need by 2012
Develop	Upgrade Local L1 trigger (multiple z vx)	Ready in 2011
	Faster DCM-II	Ready in 2010
	Upgrade EVB switch (10 Gb/s) & machines	Need by 2011
	De-multiplex FEE	
Purchase	Real Time Trigger Analysis Farm	
Construct	T0/trigger barrel	Need by 2011

PHENIX

Future Physics
And
Exploiting the Vertex Detectors

PHENIX

Upgrades→physics capabilities→run plan

upgrade	year	Physics goal	Milest.	beam/energy
HBD	2009 & 2010 only	T_{init}, thermal e^+e^-, chiral symmetry, mesons in medium	DM6	Au+Au at $\sqrt{s_{NN}}$= 200, 62.4, 39 GeV
VTX	2011	c, b separation mid-y hadrons in 2π	DM12 DM11	200Au+Au,p+p,d+Au 500 p+p; lowE Au+Au
FVTX	2012	ψ', heavy flavor y>1	DM12	200 Au+Au,p+p,d+Au 500 GeV p+p
μ trigger μTr FEE RPC	 2009/10 2011/12	W asymmetry at forward rapidity	HP8 HP12	500 GeV p+p
DAQTrig 2010	2010-12	Heavy flavor with RHIC-II luminosity	~ *all*	200 GeV Au+Au 200, 500 GeV p+p
FOCAL	2013?	$\perp$ spin γ, γ-jet; yields	HP13 DM8	p+p, d+Au (Au+Au)

What are the properties of the QCD liquid?

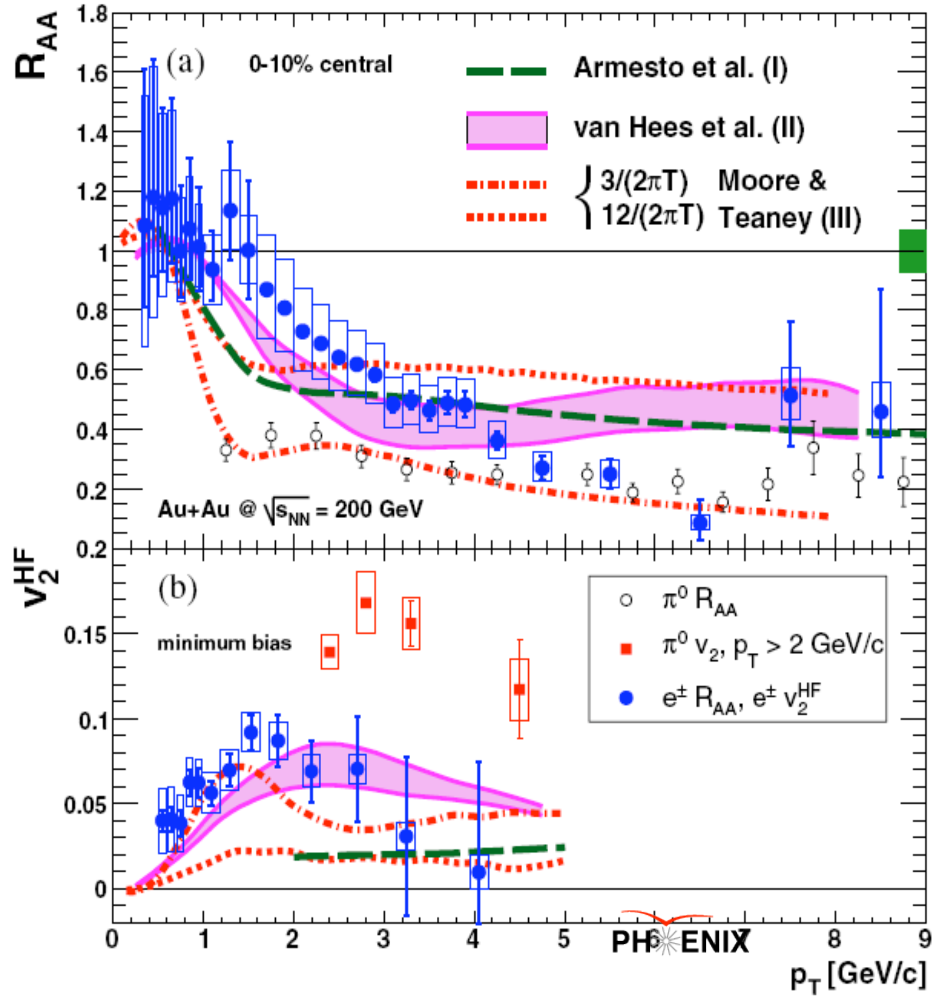
- **J/ψ flow (coalescence vs. screening) and screening length?**
  J/ψ v_2 , spectroscopy of heavy quark bound states
- **How is energy deposited to/transported in the medium?**
  γ-h correlations, h-h correlations, full jets, fate of direct γ
- **Evidence for chiral symmetry restoration?** ***Low mass e^+e^-***
- **Are b quarks stopped by the medium?** ***separate c & b***
- **Can we see gluon saturation?** ***x depend. of π^0 in d,Au + Au***
- **How do highest energy densities differ?**
- **Where is the QCD critical point?**

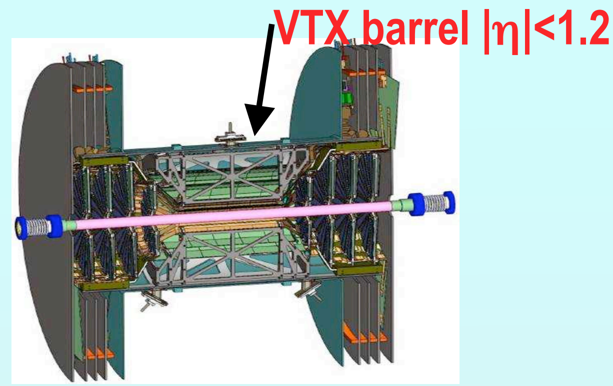
→ Extend sensitivity via increased integrated luminosity
short term: order of magnitude $\int\mathcal{L}$ over existing Run-4!
combined Run-7 + Run-10
→ longer term: RHIC-II luminosity Au+Au with VTX,FVTX,NCC
c/b separation, scan γ and π^0 vs. x
→ U+U in Run-12 (energy density ~ 60% higher than Au+Au)

PHENIX

VTX Physics

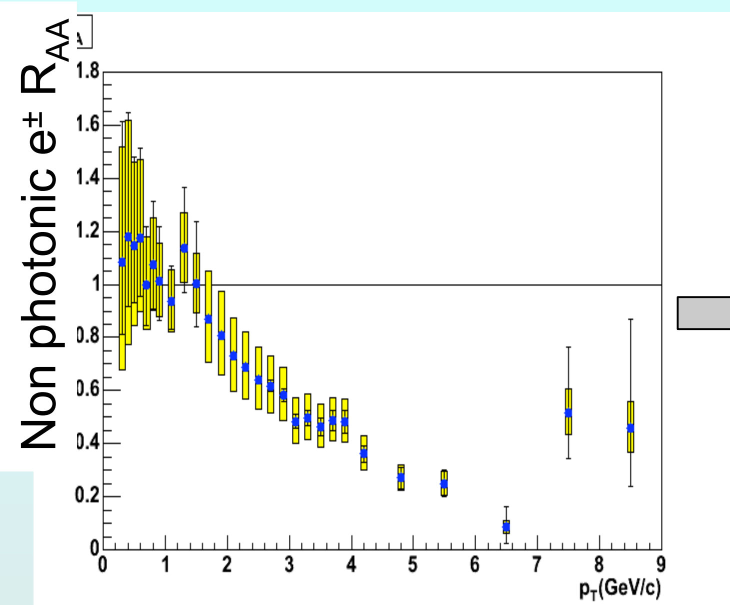
PRL 98, 172301 (2007)



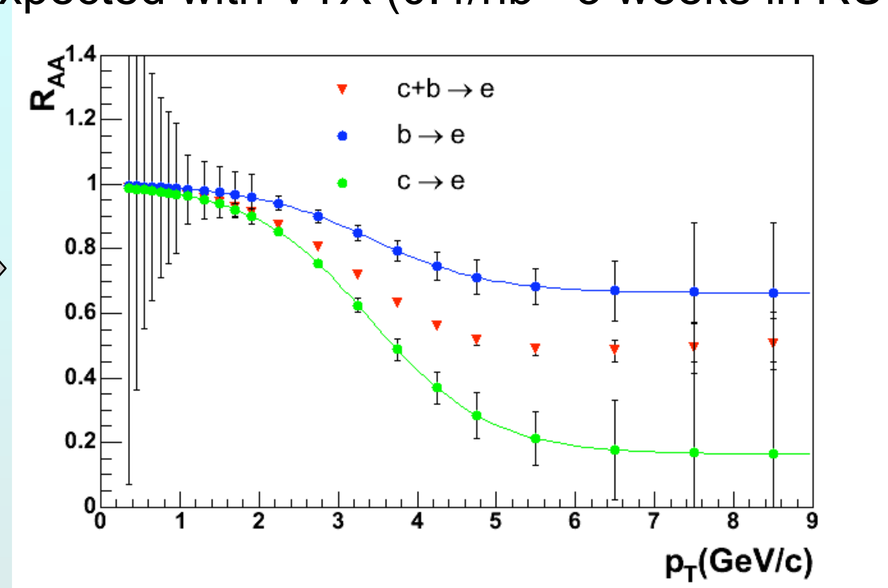


- **Heavy Flavor probes via displaced lepton vertex**
  - $R_{AA}(p_T)$ of $e^{\pm}$ from c, b decay, separated
  - v_2 (p_T) of $e^{\pm}$
- **Jet tomography (di-hadron, γ-hadron, c-hadron correlations)**
  - Large acceptance tracker
- **Gluon polarization ΔG(x) in polarized p+p**
  - Double spin asymmetry A_{LL} of heavy flavor (separated c,b)
  - A_{LL} via γ-jet

VTX Design Performance

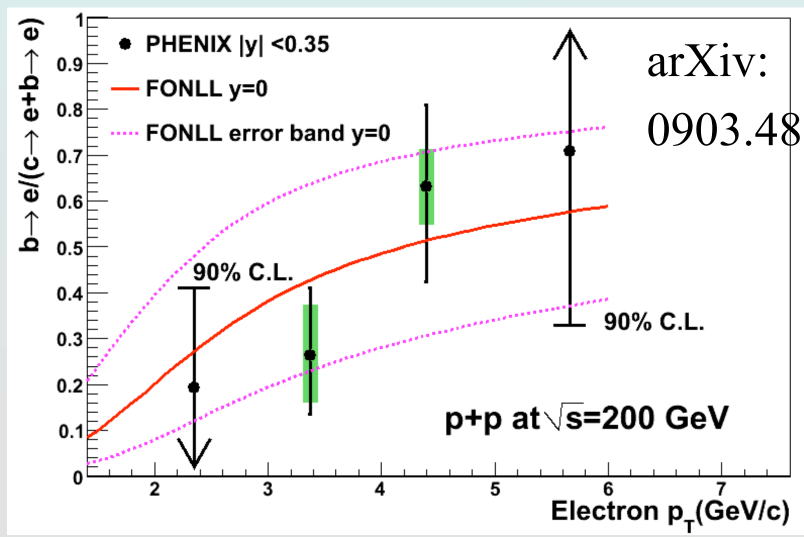


Expected with VTX (0.4/nb ~3 weeks in RUN11)



- In single electrons at high p_T b component is not small
- VTX can separate b and c by detecting displaced e vertex

  (full MC chain with detector response & analysis code)



arXiv: 0903.4851

Tune simulation to testbeam data

Charge distribution in X and U

X/U charge sharing

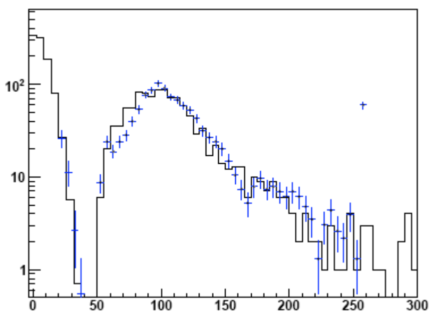


Figure 1: ADC distribution for X readout for testbeam (black histogram) and simulation (blue points). Note, that in simulation noise is cut off below ADC=20.

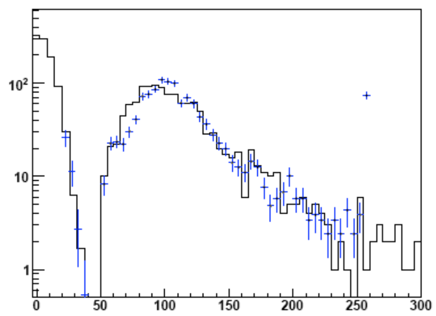
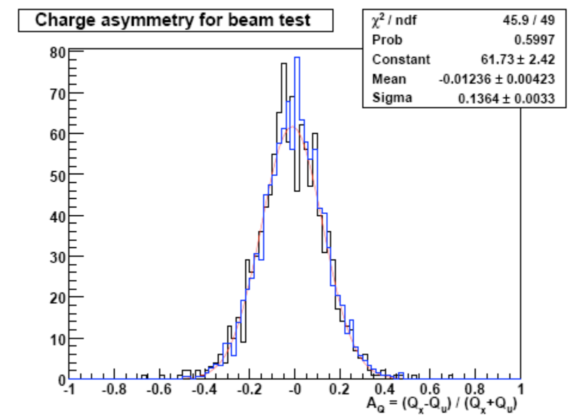


Figure 2: ADC distribution for U readout for testbeam (black histogram) and simulation (blue points). Note, that in simulation noise is cut off below ADC=20.



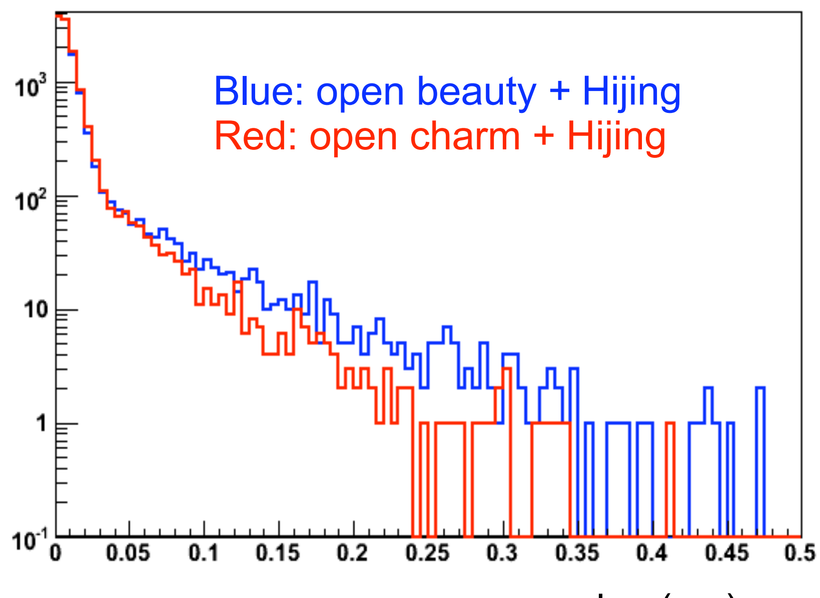
: Charge sharing distribution for for test beam results (black) and simulation Red curve is the fit to the test beam results.

- Stripixel simulation reproduces 120 GeV proton data.
- No change required in ADC gain parameter in the simulation.
- X/U charge sharing in the beam test data reproduced after minor tuning of a simulation parameter

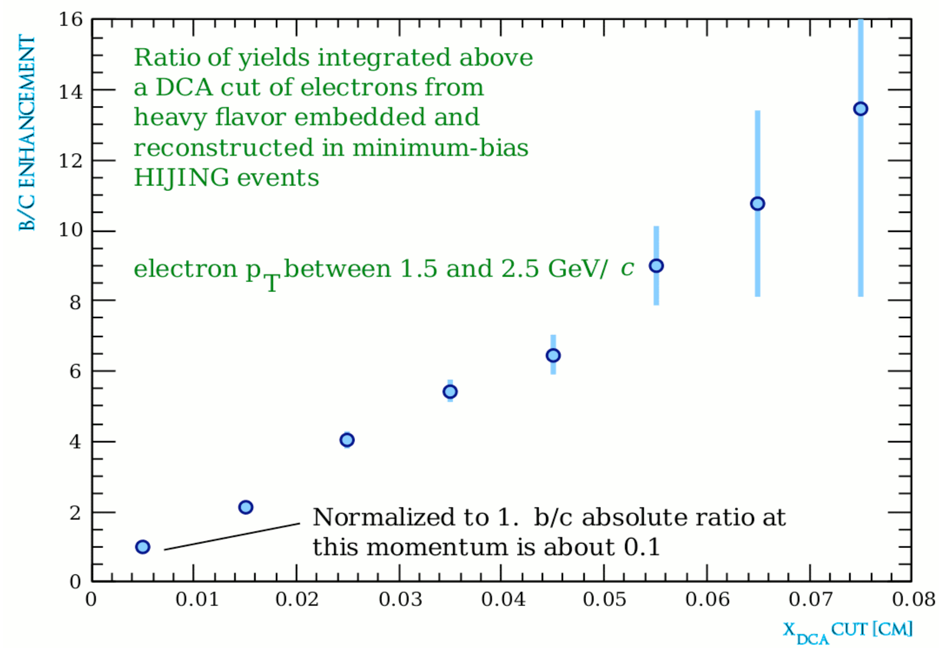
PHENIX

Blind analysis challenge

Heavy flavor electrons merged in MB Au+Au Hijing events. All transverse momenta.



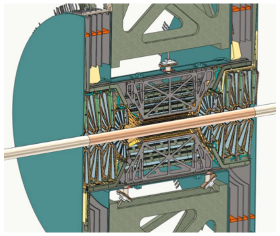
Example of c/b separation by deconvolution of DCA distribution



Current status:

- Software and integration into PHENIX framework complete.
- Simulated DSTs produced. Currently increasing available statistics.
- Step 1: “non-blind” analysis to tune software.
- Step 2: measure c/b ratio in “blind” sample, iteratively.

PHENIX ***EXERCISES VTX PHYSICS ANALYSIS BEFORE RUN-11***



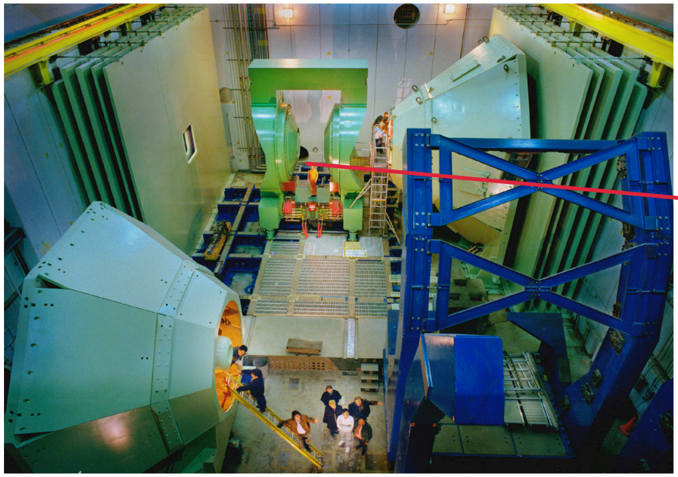
Forward Silicon Vertex Detector (FVTX)

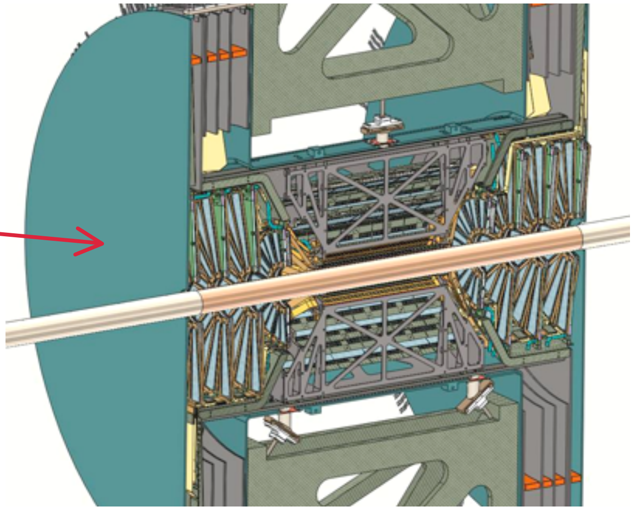
Single Muons:

- Precision heavy flavor and hadron measurements at forward rapidity
- Separation of charm and beauty
- Additional W background rejection

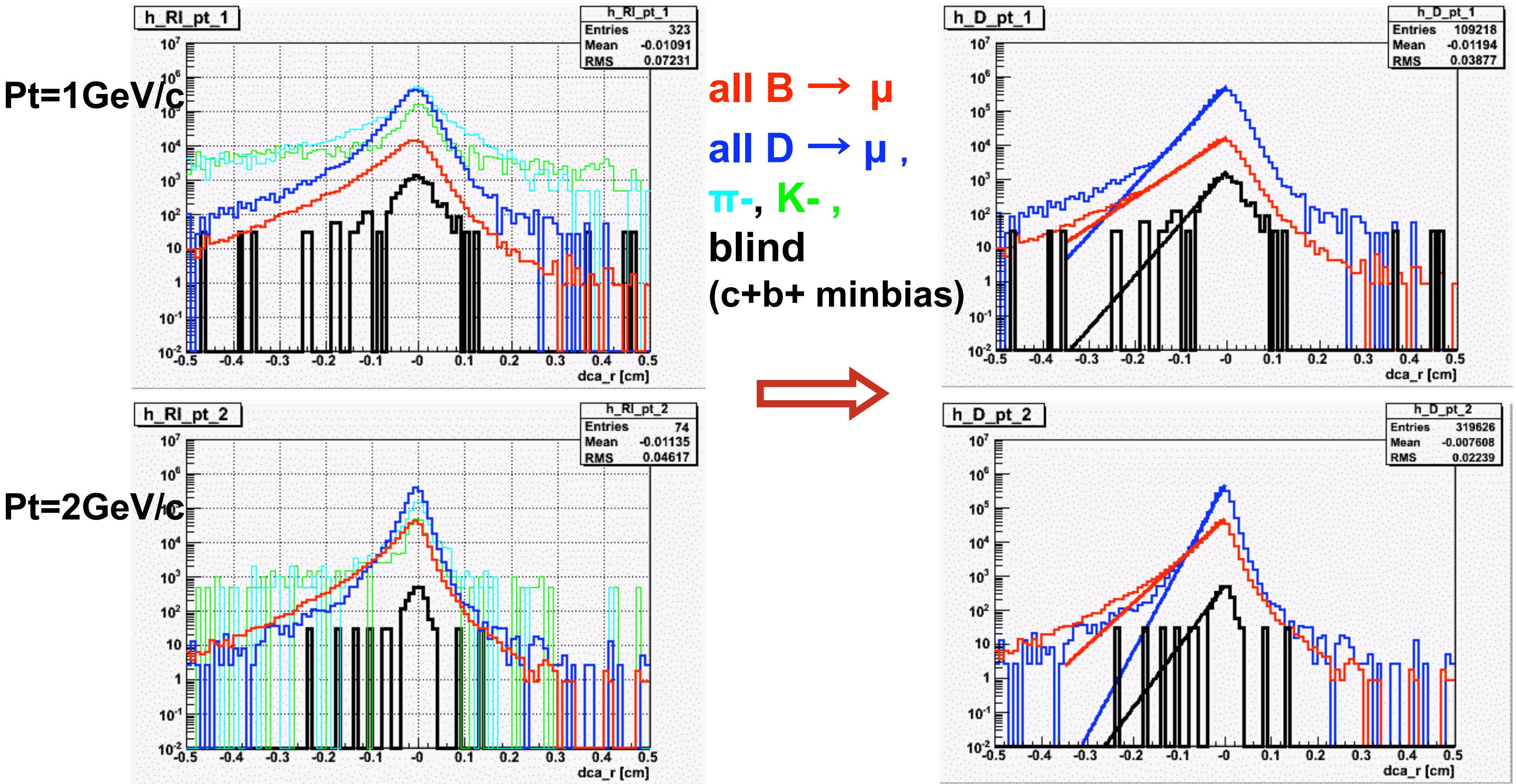
Dimuons:

- First direct bottom measurement via $B \rightarrow J/\psi$
- Separation of J/ψ from ψ' with improved resolution and S:B
- First Drell-Yan measurements from RHIC



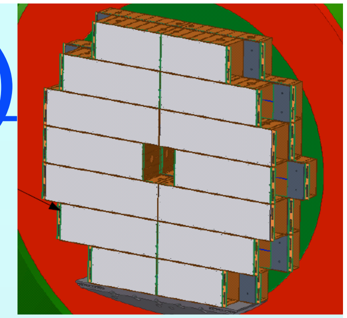


FVTX blind analysis challenge



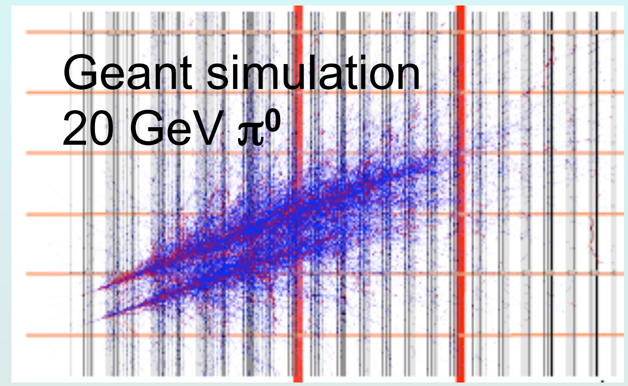
From dca_r distribution, fit and extract the ratio of c/b at each p_T bin
Now running 10 million blind events

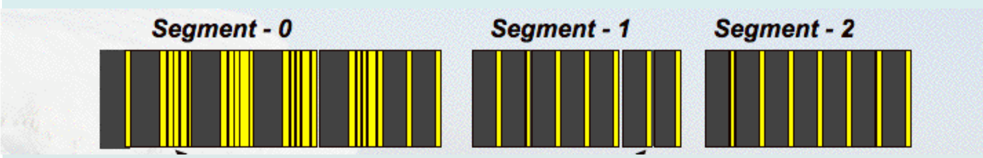
FOrward CALorimeter (FOCAL)



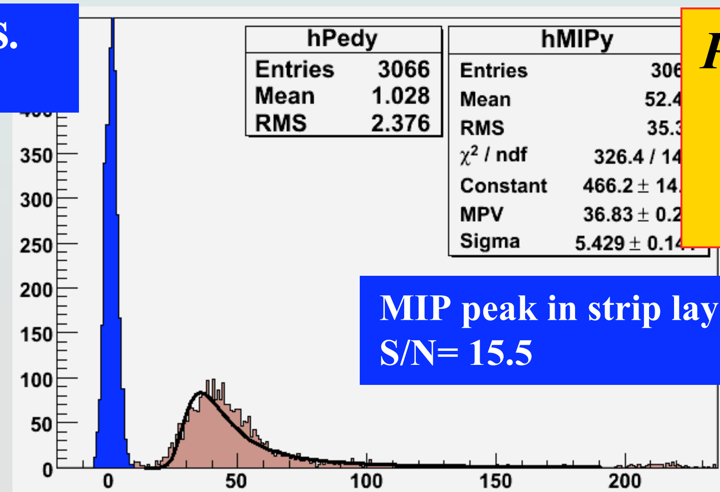
Silicon pads +silicon strips +tungsten

- Provides calorimeter coverage in the range $1.5 < \eta < 3.0$
  - No calorimeter coverage in this pseudorapidity range in PHENIX
  - Shadows both the Muon spectrometer and silicon FVTX endcaps
- 3 longitudinal segments including preshower for γ / π^{o} separation
  - 21 Xo
  - $\Delta E/E \sim 23\%/E^{1/2}$
- Low x γ,π^0 for ΔG, gluon saturation; A_N (π^0, jets)
- Two particle correlations with γ -jet





FOCAL Test at CERN PS.
$\Delta E/E \sim 23\%/E^{1/2}$



MIP peak in strip layer
S/N= 15.5

PROPOSAL IN FALL 2009

Issues and Concerns

- **Successful spin program requires**
  - Improved polarization at 500 GeV (in 2011)
  - Increased luminosity at 200 GeV (after 2012)
- **Manpower continues to be a concern**
  - Upgrades & new physics opportunities maintain collaboration momentum
  - But LHC and J-PARC offer attractive options
  - Special challenge is international engagement
  - *DOE support through ops, ARRA funds is key!*
- **Need same commitment to university groups**
  - It is where many of the people are
  - Crucial role in PHENIX operations
    - many subsystems built & run by universities

PHENIX

Summary and Outlook

- **PHENIX is extraordinarily effective and productive**
  - Sensitivity, high rate capability, superb data throughput

- **RHIC producing compelling nuclear physics**
  - Broad intellectual impact on other fields
  - Attracts young people to nuclear physics

- **Exciting short/med term future → characterization of QGP**
  - Upgrades: new observables & reach
  - VTX software will be ready with the hardware
- **Explore strongly coupled liquids → future through 2020**
  - August collaboration meeting: 2nd decade of PHENIX
    - anticipate BNL call for new decadal plan
  - Will require further upgrades to explore questions unknown in 2001 and ensure robust detector to 2020

PHENIX

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System Electronics Laboratory, Seoul National University, Seoul, South Korea
Yonsei University, IPAP, Seoul 120-749, Korea
IHEP Protvino, State Research Center of Russian Federation, Institute for High Energy Physics,
Protvino, 142281, Russia
Joint Institute for Nuclear Research, 141980 Dubna, Moscow Region, Russia
Russian Research Center "Kurchatov Institute", Moscow, Russia
PNPI, Petersburg Nuclear Physics Institute, Gatchina, Leningrad region, 188300, Russia
Saint Petersburg State Polytechnic University, St. Petersburg, Russia
Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Vorob'evy Gory,
Moscow 119992, Russia
Department of Physics, Lund University, Box 118, SE-221 00 Lund, Sweden

PHENIX **14 Countries; 70 Institutions**

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Collider-Accelerator Department, Brookhaven National Laboratory, Upton, NY 11973-5000, U.S.
Physics Department, Brookhaven National Laboratory, Upton, NY 11973-5000, U.S.
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University of Colorado, Boulder, CO 80309, U.S.
Columbia University, New York, NY 10027 and Nevis Laboratories, Irvington, NY 10533, U.S.
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Florida State University, Tallahassee, FL 32306, U.S.
Georgia State University, Atlanta, GA 30303, U.S.
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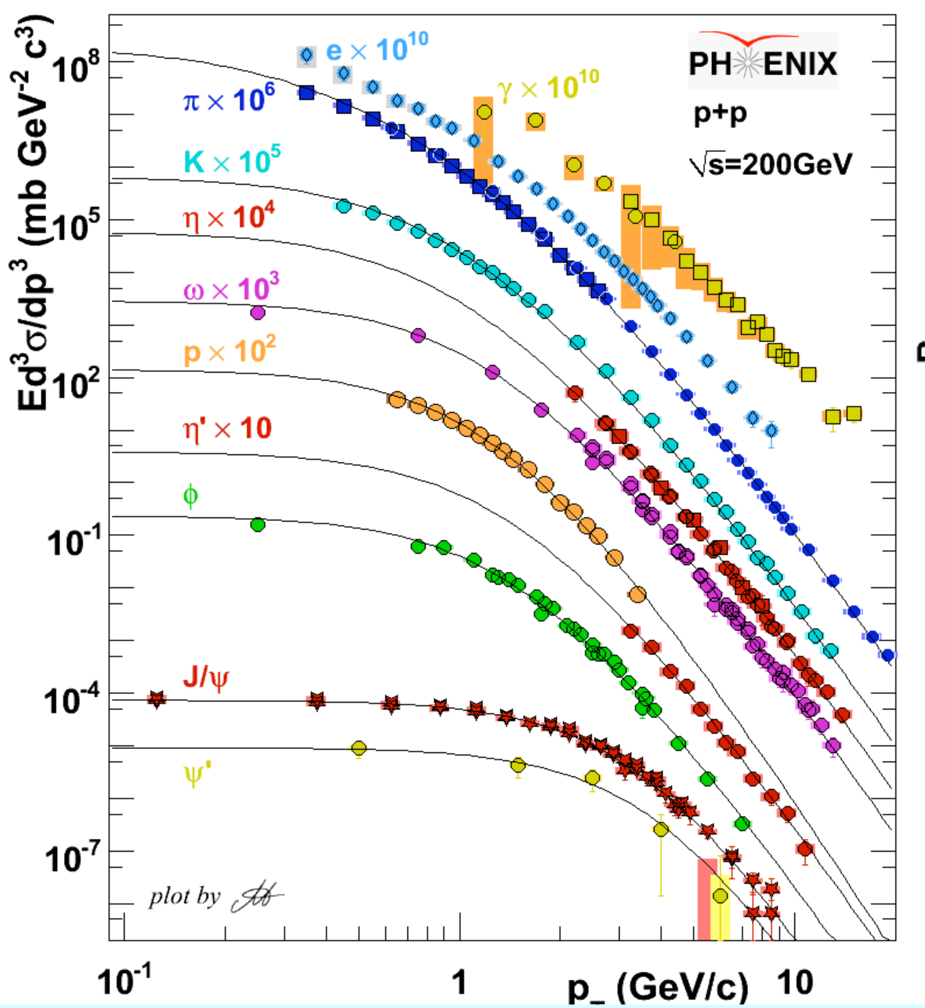
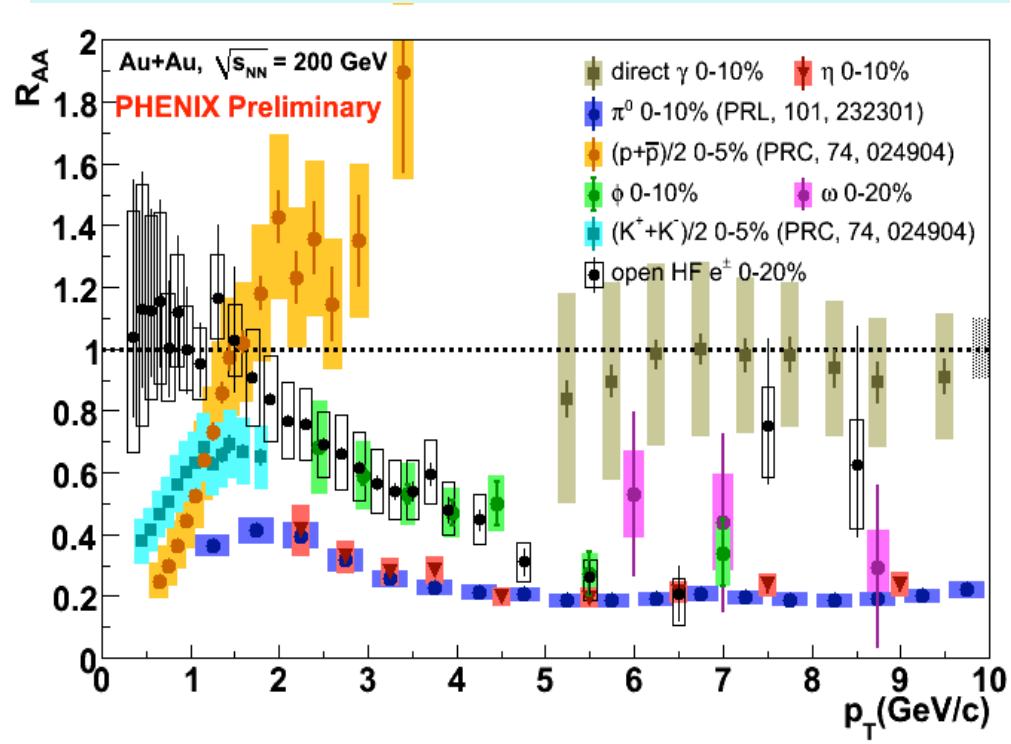
University of Tennessee, Knoxville, TN 37996, U.S.
Vanderbilt University, Nashville, TN 37235, U.S.

- backup slides

Unprecedented range & precision!



Suppression in central Au+Au



Universal Levy fit of meson & (non-strange) baryon spectra in p+p → m_T scaling

Detector issues with high luminosity?

- PHENIX detectors are primarily fast detectors
  - High rate anticipated in original design
- Wire chamber aging at more rapid rate
  - Beginning evaluation of options
- Change in calibration strategies, particularly for DC
  - Completed & implemented
  - Use hits from reconstructed tracks to calibrate drift time
- Pattern recognition and efficiency under study

PHENIX

Backgrounds at 500 GeV

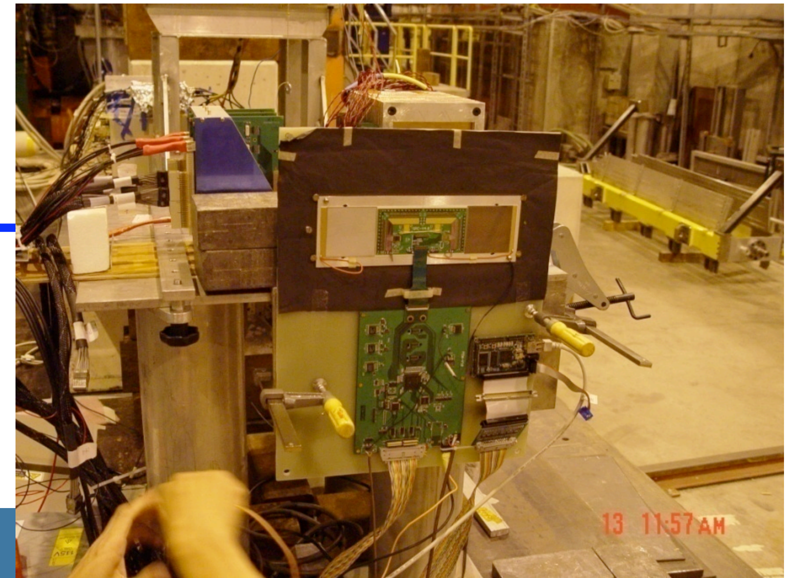
- Data analysis underway…

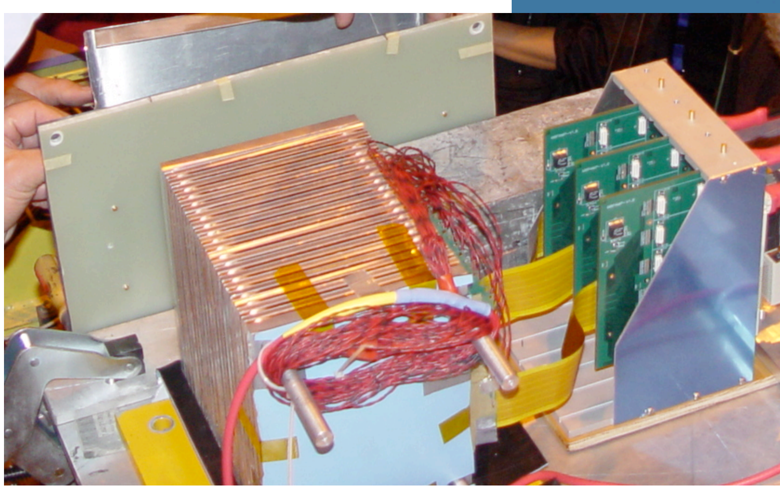
- First taste of >1 MHz interaction rates
- Demonstrated operability of detectors
- Multiple collisions per crossing and in adjacent crossings
  - Learned how to deal with it
  - Revised drift chamber calibration approach
- Scaling the backgrounds to the collision rate worked OK as a rule of thumb
- RPCs provided key monitoring instrumentation
  - Probably would like to install additional monitors

PHENIX

FOCAL R&D ongoing

Test beam to demonstrate response, benchmark simulation





Future HI Milestones

Requires upgrade

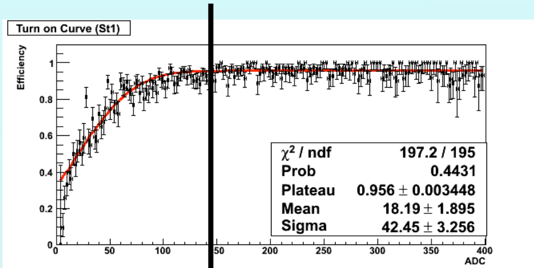
Year	#	Milestone
2009	DM4	Perform realistic three-dimensional numerical simulations to describe the medium and the conditions required by the collective flow measured at RHIC.
2010	DM5	Measure the energy and system size dependence of J/Ψ production over the range of ions and energies available at RHIC.
2010	DM6	Measure e^+e^- production in the mass range $500 \leq m_{e+e-} \leq 1000$ MeV/c2 in $\sqrt{s_{NN}} = 200$ GeV collisions.
2010	DM7	Complete realistic calculations of jet production in a high density medium for comparison with experiment.
2012	DM8	Determine gluon densities at low x in cold nuclei via p + Au or d + Au collisions.
2015	DM9 (new)	Measure bulk properties, particle spectra, correlations and fluctuations in Au + Au collisions at $\sqrt{s_{NN}}$ from 5 to 40 GeV to search for evidence of a critical point in the QCD matter phase diagram.
2014	DM10 (new)	Perform calculations including viscous hydrodynamics to quantify, or place an upper limit on, the viscosity of the nearly perfect fluid discovered at RHIC.
2014	DM11 (new)	Measure jet and photon production and their correlations in A≈200 ion+ion collisions at energies from $\sqrt{s_{NN}} = 30$ GeV up to 5.5 TeV.
2016	DM12 (new)	Measure production rates, high pT spectra, and correlations in heavy-ion collisions at $\sqrt{s_{NN}} = 200$ GeV for identified hadrons with heavy flavor valence quarks to constrain the mechanism for parton energy loss in the quark-gluon plasma.
2018	DM13 (new)	Measure real and virtual thermal photon production in p + p, d + Au and Au + Au collisions at energies up to $\sqrt{s_{NN}} = 200$ GeV.

Spin Physics Milestones

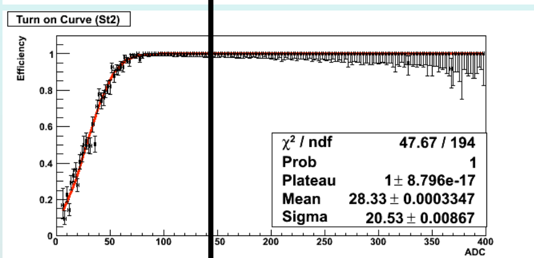
Year	#	Milestone
2013	HP8	Measure flavor-identified q and $\bar{q}$ contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.
2013	HP12	Determine if gluons have appreciable polarization over any range of momentum fraction between 1 and 30% of the momentum of a polarized proton.
2015	HP13	Test unique QCD predictions for relations between single-transverse spin phenomena in p-p scattering and those observed in deep-inelastic lepton scattering.

MUTRIG ready for physics in Run-11

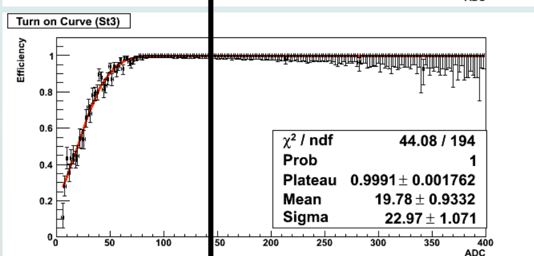
Station 1



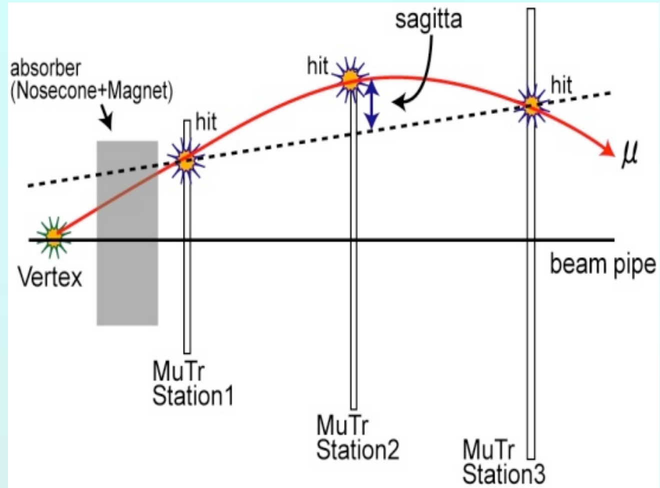
Station 2

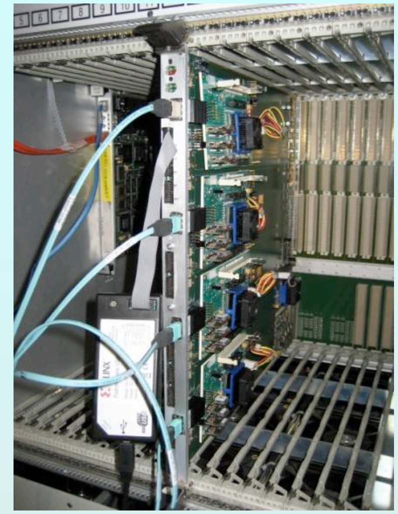


Station 3



Minimum Ionizing Particle

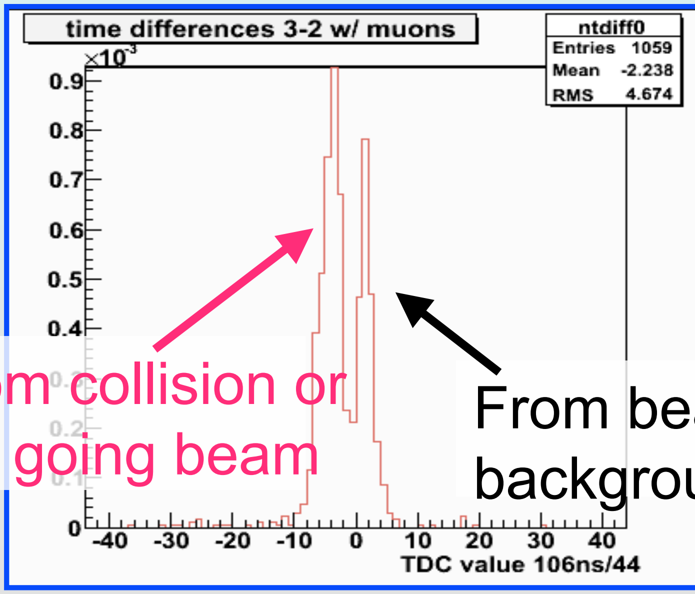




- Good efficiency for MIPs
- MUTR.N installed & read out
- Partial installation for test in MUTR.S to cover RPC
- Prototype trigger logic tested

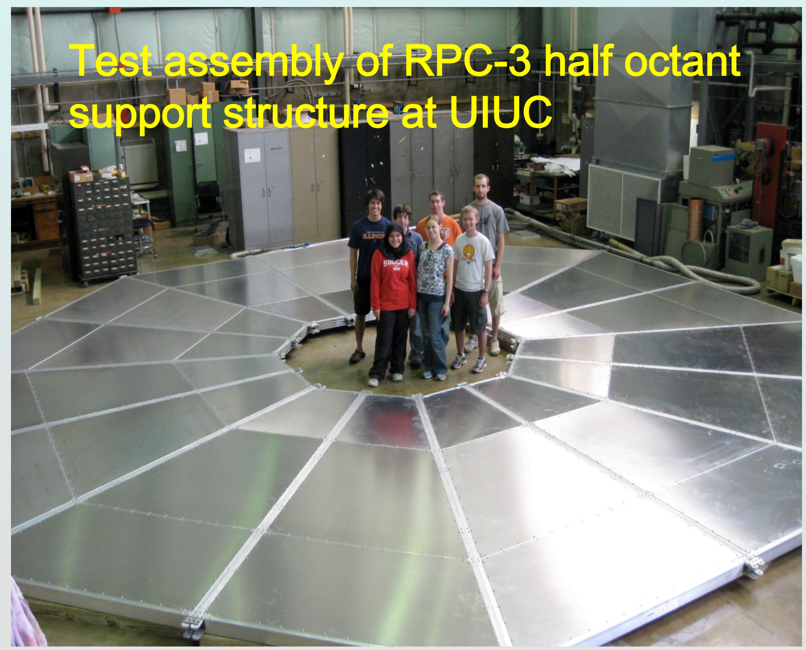
RPCs: trigger level timing

- Engineering run for sectors in 2 planes on south arm
- Timing has illuminated background already



From collision or out going beam

From beam background



PHENIX

FVTX Construction Status

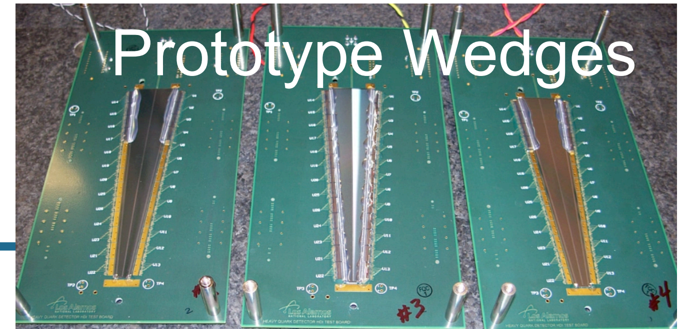
Wedge Prototypes Produced and Tested
- Successful design/test of FPHX readout chip
- Successful design/test of prototype sensor
- Working High Density Interconnect (HDI)
- All specifications met on prototypes

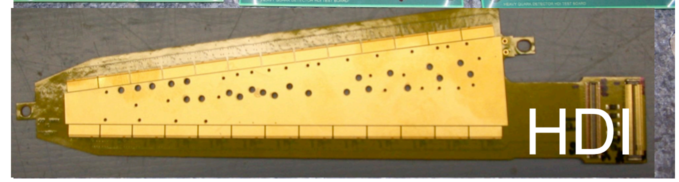
Wedge and Full Detector Assembly
- Wedge assembly procedures and fixtures developed and worked well with prototypes
- BNL area prepared for disk assembly

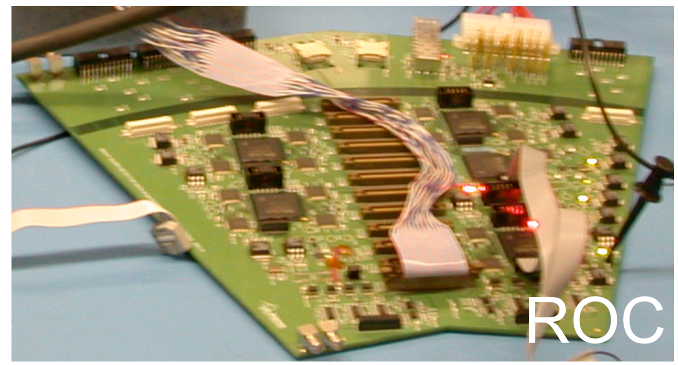
DAQ
- ReadOut Card (ROC) designed, programmed and successfully used to readout multiple wedges
- Full FEM FPGA designed and prototype in progress

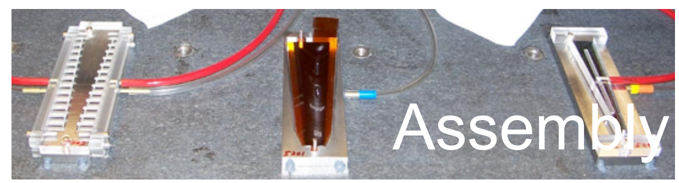
Mechanics
- Wedge, disk and cage designs (mostly) ready for production

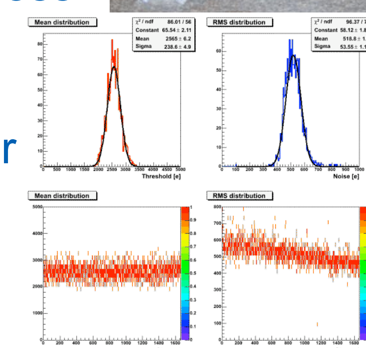
Project Complete June 2011

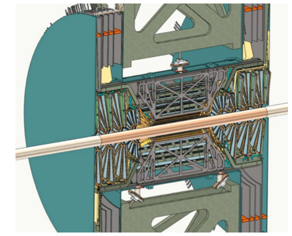








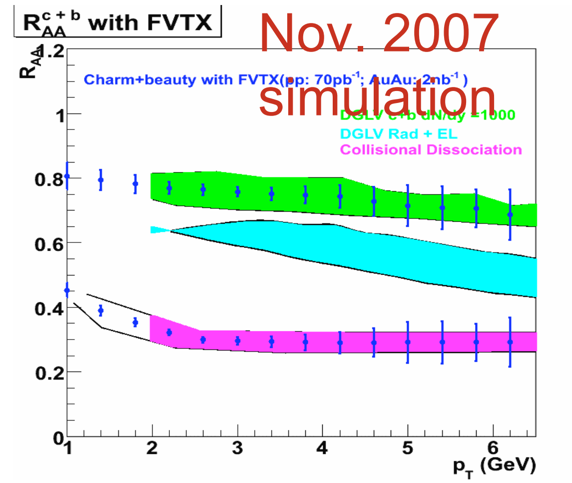




Progress on FVTX Review Homeworks

"A complete heavy flavor R_{AA} analysis chain with realistic DCA errors should be demonstrated "

DCA with current design shown to be same as Nov. 2007 Science Review. Blind Analysis underway to reproduce physics plots.

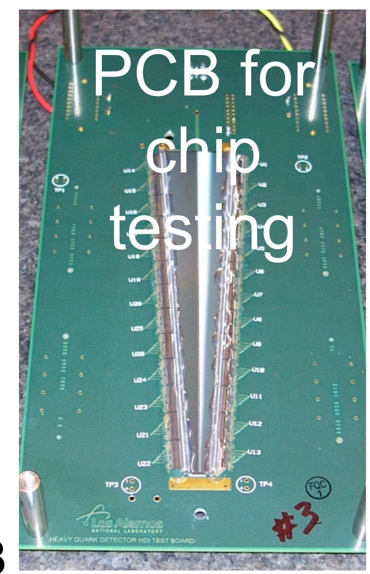


"The simulation package for the readout chain should be enlarged to include capability to determine where the high data rate bottlenecks occur"

Full FPGA simulation performed, as well as offline simulation to look at bottlenecks

"The collaboration should design a normal printed circuit board as the first multi-chip module to test the FPHX prototype run."

Done. Used to establish multi-chip performance and allowed 2nd round FPHX prototype to be submitted



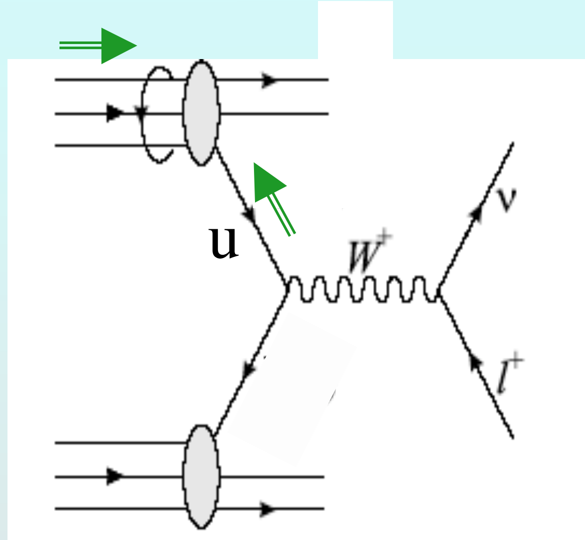
ΔG not large: sea quarks polarized? d vs. u?

Probe $\Delta\bar{q}$-Δq via W production

$$\Delta d + \bar{u} \rightarrow W^-$$
$$\Delta\bar{u} + d \rightarrow W^-$$
$$\Delta\bar{d} + u \rightarrow W^+$$
$$\Delta u + \bar{d} \rightarrow W^+$$

$\vec{p}$

p unpol.



100% Parity-violating: — $$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

Start: 2009(tests)/2010(trigger) with 500 GeV p+p

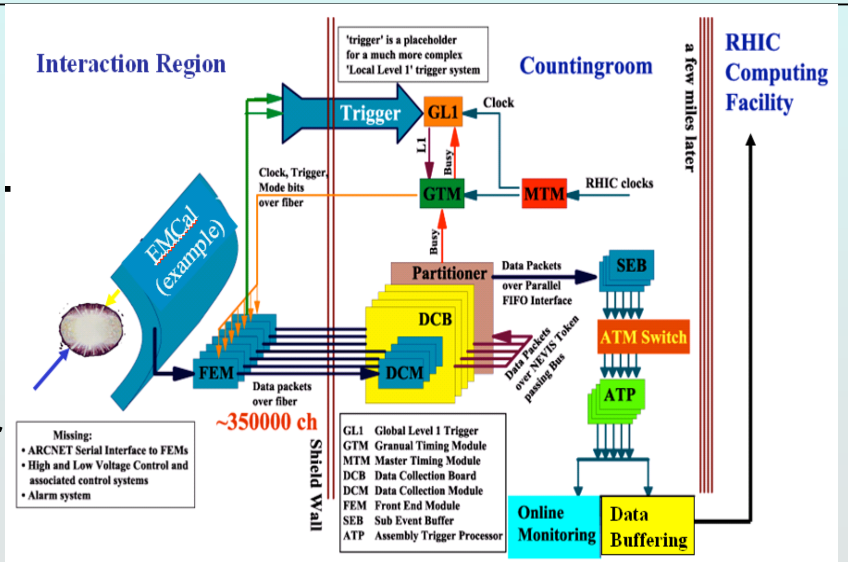
PHENIX

PHENIX DAQ

PHENIX has fully pipelined “deadtimeless” DAQ (+Front End Electronics and Triggers).

Similar to CDF,D0 (with slower clock) and ATLAS, CMS (with faster clock).

Thus, we can run at close to Level-1 trigger capacity at very high livetime.

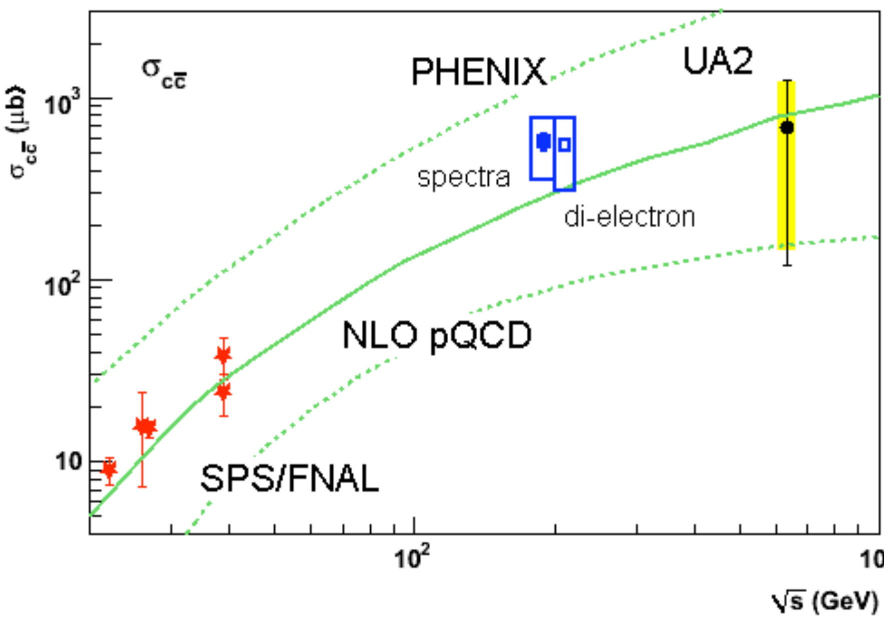


Level-1 triggers: Interaction triggers (BBC, ZDC)
Muon triggers (MuID)
Photon triggers (EM Calorimeter)
Electron triggers (EM Calorimeter + RICH)

Charm & bottom cross section in p+p

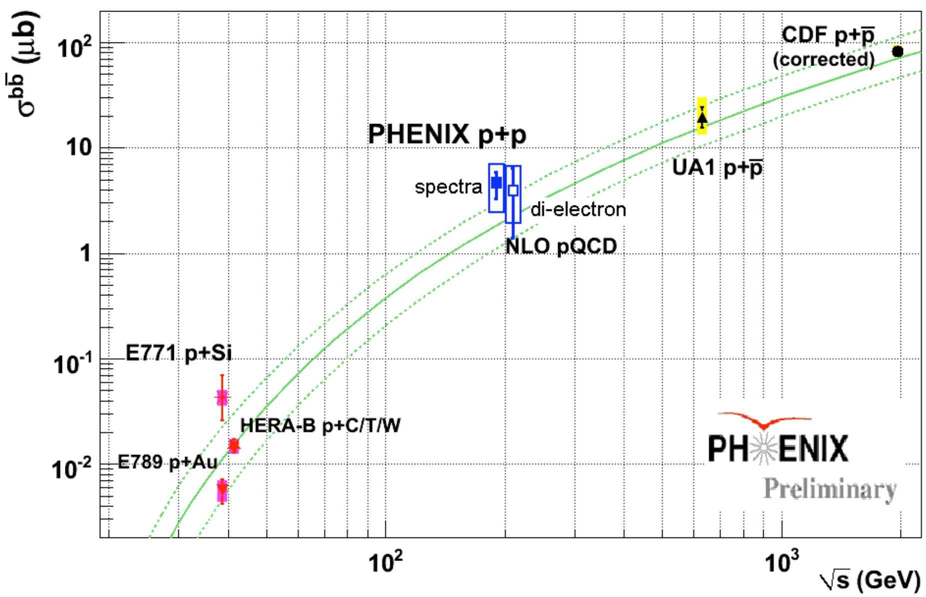
CHARM

Dilepton measurement in agreement with single electron, single muon, and with FONLL (upper end)



BOTTOM

Dilepton measurement in agreement with measurement from e-h correlation and with FONLL (upper end)



PHENIX run history

Run	Year	Species	$\sqrt{s_{NN}}$ (GeV)	$\int L\,dt$	N_{Tot}	p+p Equivalent	Data Size
01	2000	Au+Au	130	1 μb^{-1}	10M	0.04 pb^{-1}	3 TB
02	2001/2002	Au+Au	200	24 μb^{-1}	170M	1.0 pb^{-1}	10 TB
		p+p	200	0.15 pb^{-1}	3.7G	0.15 pb^{-1}	20 TB
03	2002/2003	d+Au	200	2.74 nb^{-1}	5.5G	1.1 pb^{-1}	46 TB
		p+p	200	0.35 pb^{-1}	6.6G	0.35 pb^{-1}	35 TB
04	2004/2004	Au+Au	200	241 μb^{-1}	1.5G	10.0 pb^{-1}	270 TB
		Au+Au	62.4	9 μb^{-1}	58M	0.36 pb^{-1}	10 TB
05	2004/2005	Cu+Cu	200	3 nb^{-1}	8.6G	11.9 pb^{-1}	173 TB
		Cu+Cu	62.4	0.19 nb^{-1}	0.4G	0.8 pb^{-1}	48 TB
		Cu+Cu	22.5	2.7 μb^{-1}	9M	0.01 pb^{-1}	1 TB
		p+p	200	3.8 pb^{-1}	[illegible]	[illegible]	262 TB
06	2006	p+p	200	10.7 pb^{-1}	[illegible]	[illegible]	310 TB
		p+p	62.4	0.1 pb^{-1}	28G	0.1 pb^{-1}	25 TB
07	2007	Au+Au	200	0.813 nb^{-1}	5.1G	33.7 pb^{-1}	650 TB
08	2008	d+Au	200	80 nb^{-1}	160G	32.1 pb^{-1}	437 TB
		p+p	200	5.2 pb^{-1}	115G	5.2 pb^{-1}	118 TB

0.6 PB via Grid transfer to CC-J in 05/06

PHENIX

Have met all RHIC milestones to date

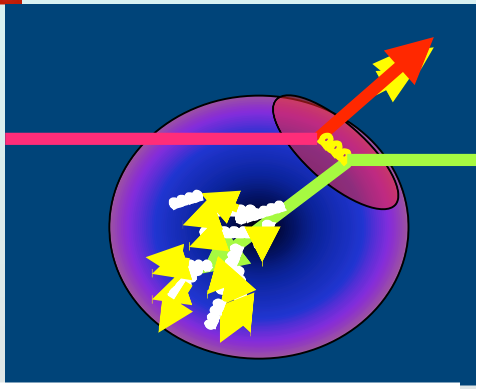
Year	Milestone	Status
2005 **DM1**	Measure J/Ψ production in Au + Au at $\sqrt{s_{NN}}$ = 200 GeV.	Achieved
2007 **DM2**	Measure flow and spectra of multiply-strange baryons in Au + Au at $\sqrt{s_{NN}}$ = 200 GeV.	Exceeded
2007 **DM3**	Measure high transverse momentum jet systematics vs. $\sqrt{s_{NN}}$ up to 200 GeV and vs. system size up to Au + Au.	Exceeded
2008 **HP1**	Make measurements of spin carried by the glue in the proton with polarized proton-proton collisions at center of mass energy, $\sqrt{s_{NN}}$ = 200 GeV.	Achieved

How does this exotic matter work? properties!

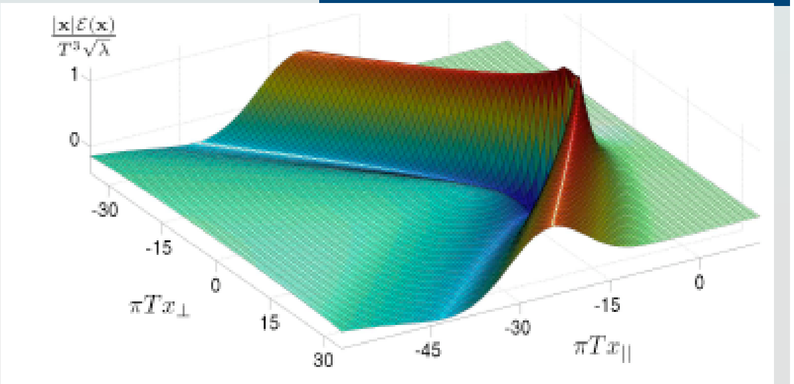
- Viscosity/entropy ratio is very low
  a "perfect" liquid
  How low? Why? Consequences?

Example of the viscosity of milk. Liquids with higher viscosities will not make such a splash when poured at the same velocity.

- Opacity very high
  Effectively stops quarks & gluons
  Do even b quarks screech to a halt?
  How and why?



- Matter may support shock waves
  What's the speed of sound?
  Damping?
  Other transport properties?

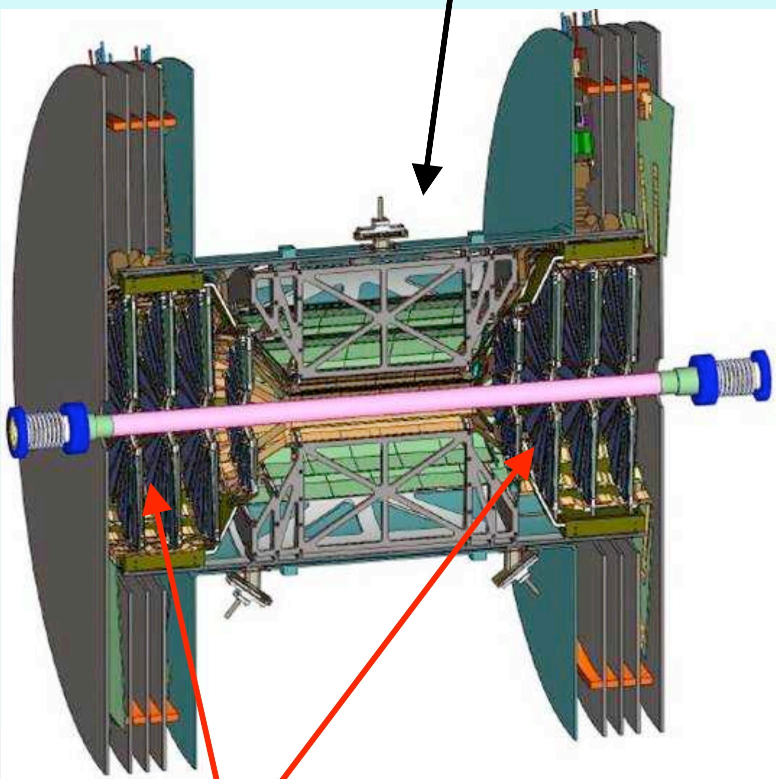


- Color screening magnitude?

PHENIX

Silicon Vertex (VTX & FVTX)

VTX barrel $|\eta|<1.2$

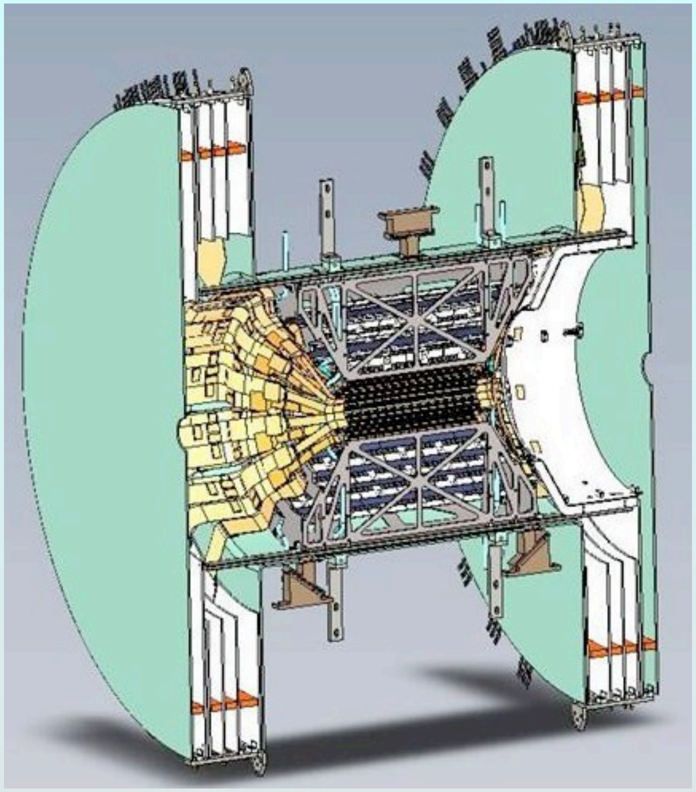


FVTX endcaps
$1.2<|\eta|<2.7$
mini strips

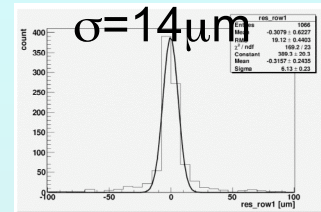
- **VTX: silicon VerTeX barrel tracker**
  - Fine granularity, low occupancy
    - $50\mu m \times 425\mu m$ pixels for L1 and L2
    - R1=2.5cm and R2=5cm
  - Stripixel detector for L3 and L4
    - $80\mu m \times 1000\mu m$ pixel pitch
    - R3=10cm and R4=14cm
  - Large acceptance
    - $|\eta|<1.2$, almost 2π in ϕ plane
  - Standalone tracking

- **FVTX: Forward silicon VerTeX tracker**
  - 2 endcaps with 4 disks each
  - pixel pad structure ($75\mu m$ x 2.8 to 11.2 mm)

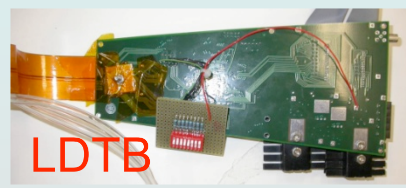
VTX status

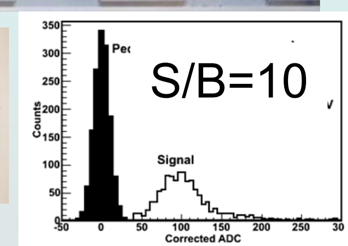


Pixel full ladder



Stripixel ladder



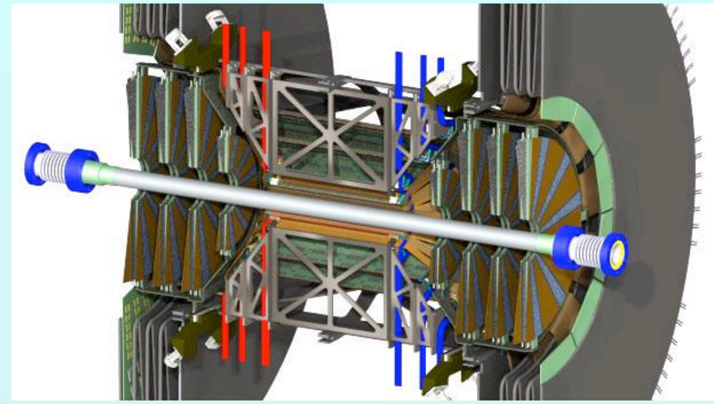


- All components are in production
- Very successful review in June 2009.

"The detector now appears to be on a trajectory leading to a likely on-budget/on-schedule completion"

Installation in PHENIX in fall 2010

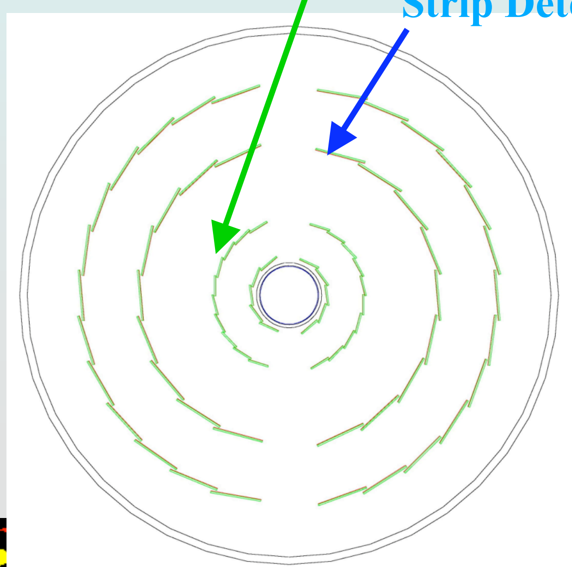
Barrel VTX Detector

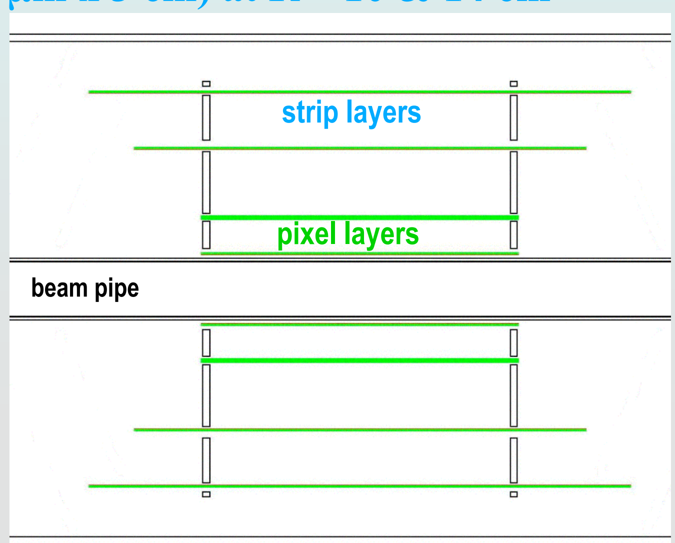


- **Specifications:**
  Large acceptance ($\Delta\phi \sim 2\pi$ and $|\eta| < 1.2$)
  Displaced vertex measurement $\sigma < 40\ \mu m$
  Charged particle tracking $\sigma_p/p \sim 5\%$ p at high pT
  Detector must work for both HI and pp collisions.
- **Technology Choice**
  Hybrid pixel detectors developed at CERN for ALICE
  Strip detectors, sensors developed at BNL with FNAL's SVX4 readout chip

Hybrid Pixel Detectors (50 μm x 425 μm) at R ~ 2.5 & 5 cm

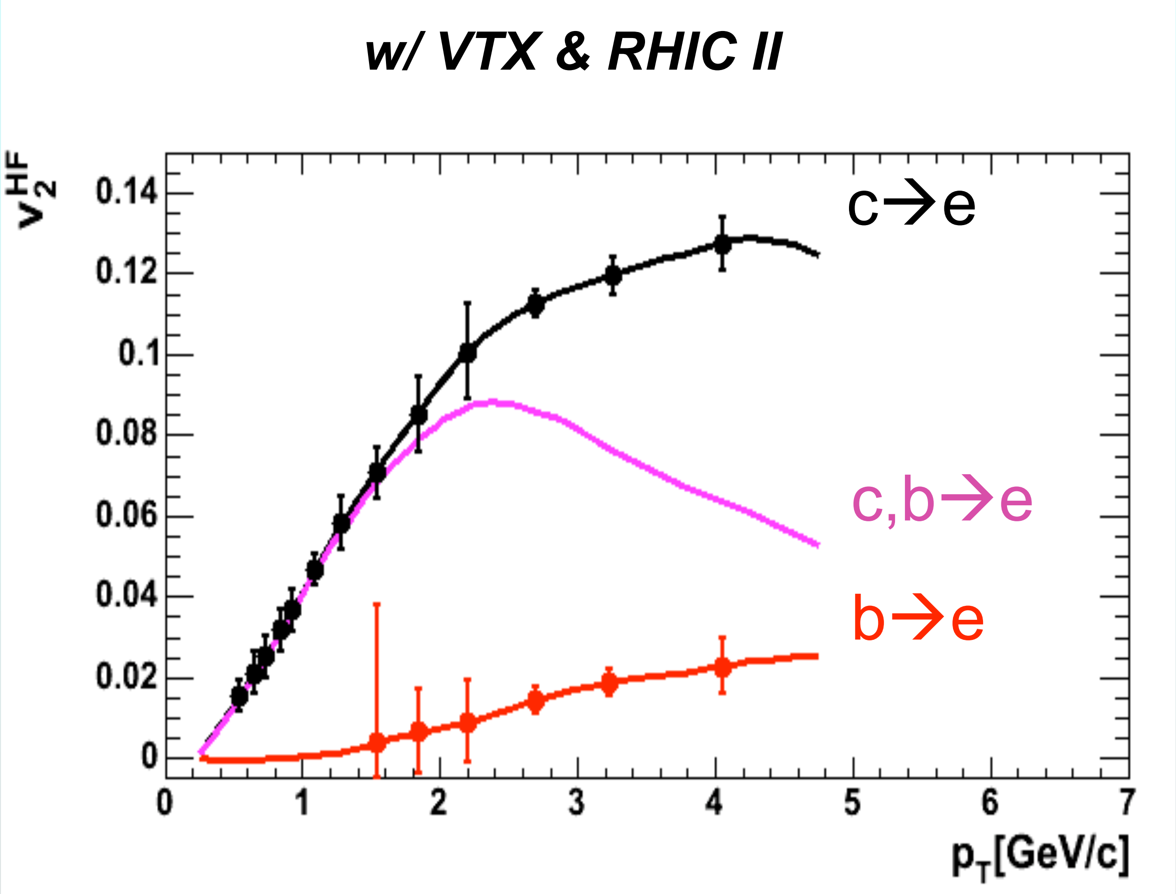
Strip Detectors (80 μm x 3 cm) at R ~ 10 & 14 cm





$|\eta|<1.2$
$\phi \sim 2\pi$
$z \sim \pm 10$ cm

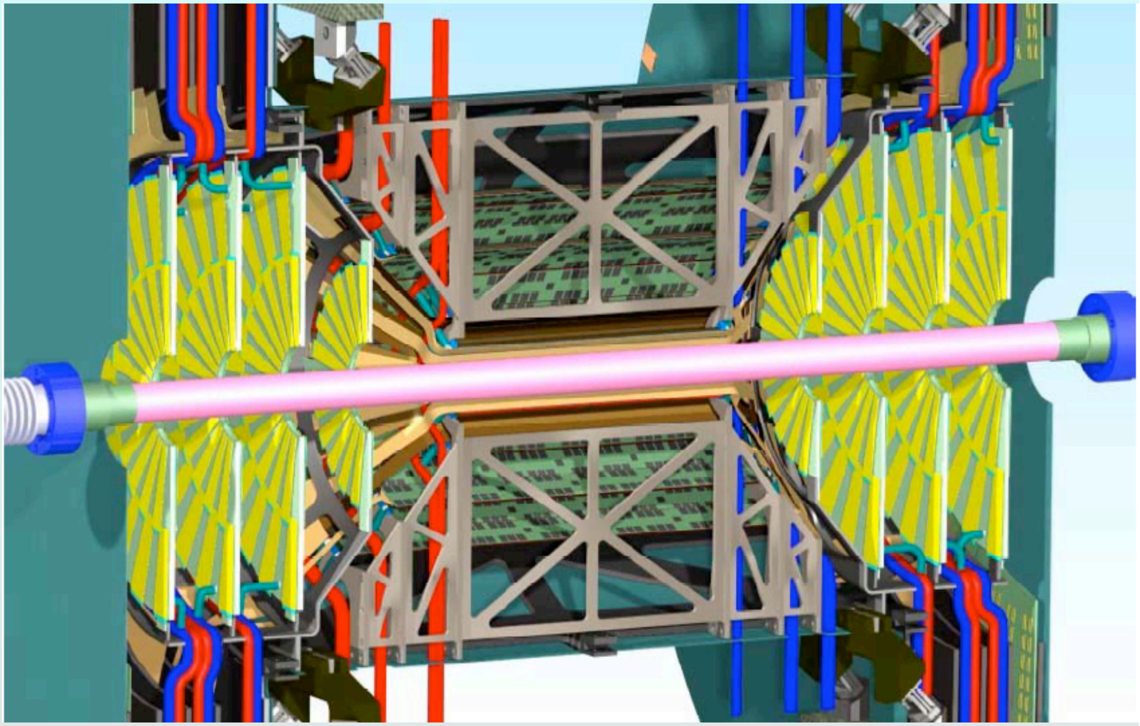
VTX performance on c,b separation



Forward Silicon Vertex Detector - FVTX

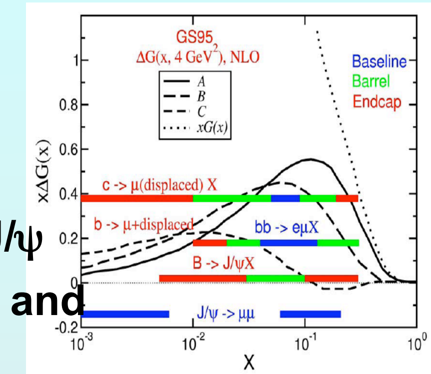
FVTX Specifications:

- 2 endcaps
- 4 pixelpad layers/endcap
- ~550k channels/endcap
- Electronics a mod of BTeV readout chip
- Fully integrated mech design w/ VTX
- 2π coverage in azimuth and $1.2 < |\eta| < 2.4$
- Better than 100 μm displaced vertex resolution

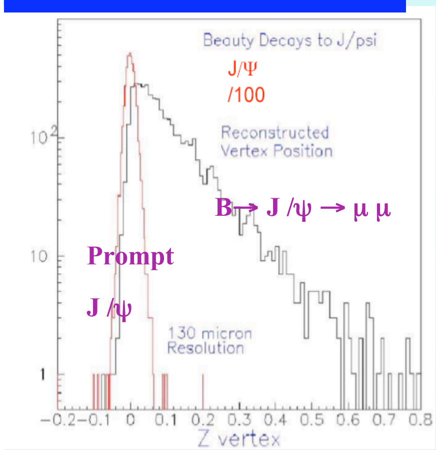


Forward Silicon Vertex Detector - FVTX

Enhanced x coverage



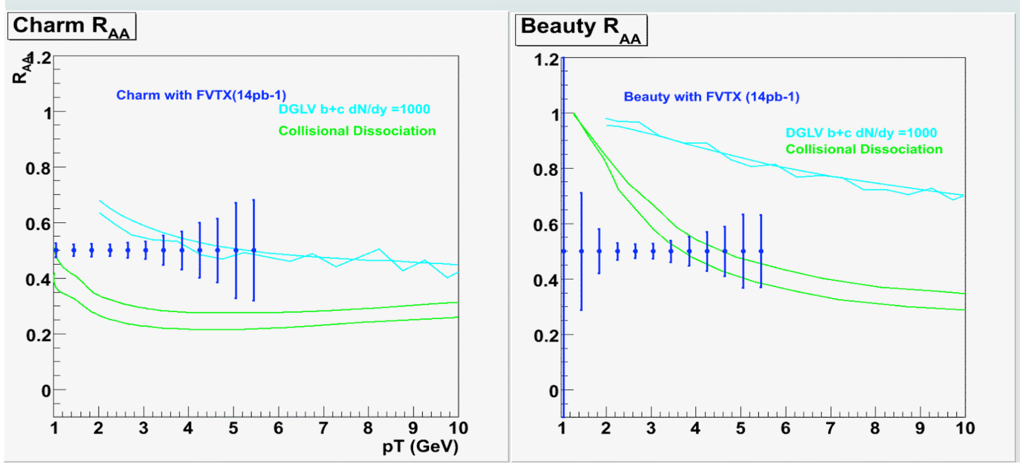
Direct measure of B



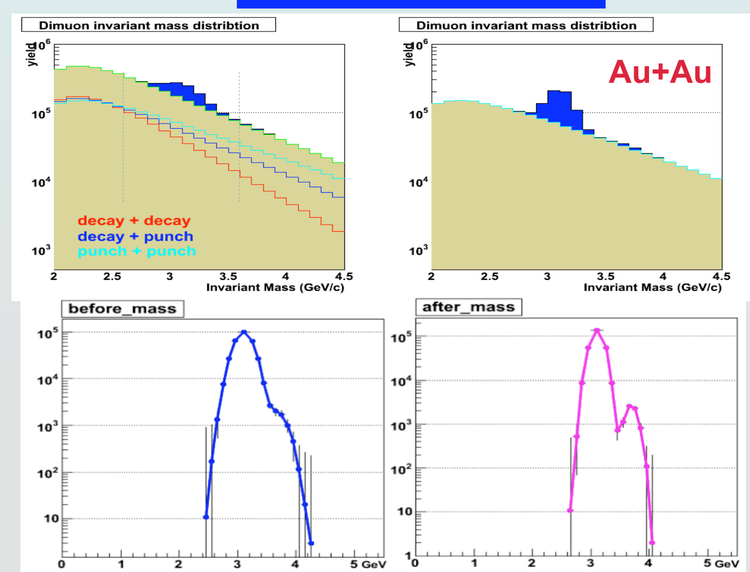
Physics Program of FVTX includes

- Resolving J/ψ and ψ' in Muon arms
- Resolving ϒ at y=0 using Muon arms
- Direct measure of B meson through displaced J/ψ
- Drell-Yan Measurements in dAu at both forward and midrapidities
- c, b ID for both HI physics & ΔG spin measurements
- Nuclear modification factor (CGC effects) in dAu using hadrons, c, b, and J/ψ

c, b suppression at forward η



J/ψ, ψ' separation



Data taking efficiency

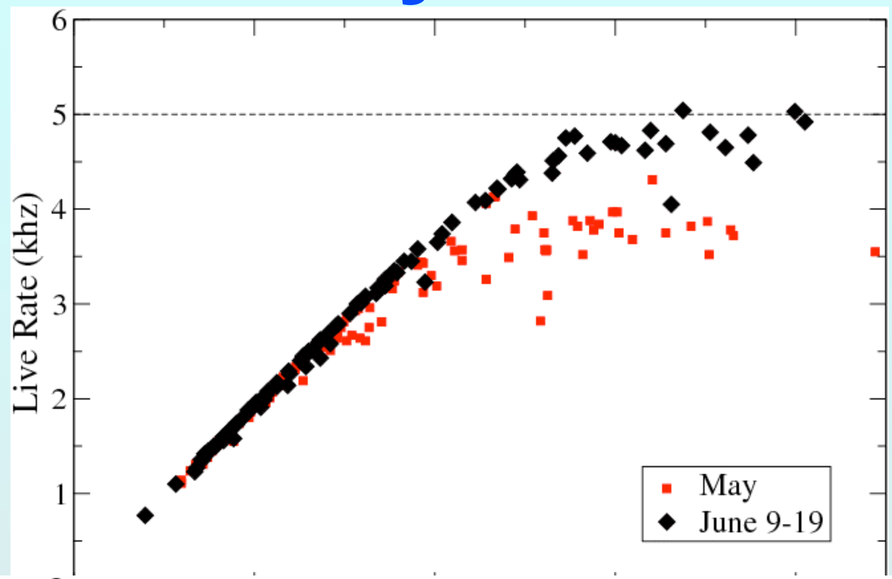
Run-7:

Up to 5 kHz event rate

700 Mb/sec

Take ~80-90% of ALL

Min bias Au+Au



Run-8 d+Au:

7 kHz event rate